I E Aust HQ

THE

SYDNEY WATER SUPPLY COMPLEX

AT

PROSPECT

A SUBMISSION FOR

3 HISTORIC ENGINEERING MARKERS

SYDNEY DIVISION
I. E. AUST
November 1993

THE PROSPECT RESERVOIR COMPLEX

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OVERVIEW

INTRODUCTION

This submission nominates three components of the Sydney Water Supply complex at Prospect, each for an Historic Engineering Marker. In conjunction with the owner, the Water Board, it is planned to unveil the plaques at a ceremony on Sunday 17 April 1994 at the beginning of Heritage Week.

The engineering items proposed for plaquing are

1. The clay-core earth embankment that creates the Prospect Reservoir.

2. The two valve houses and the contained equipment, one valve house on the upstream side of the embankment which controls the level of water take-off, and the canal valve house on the downstream side that controls the water discharging into the Lower Canal.

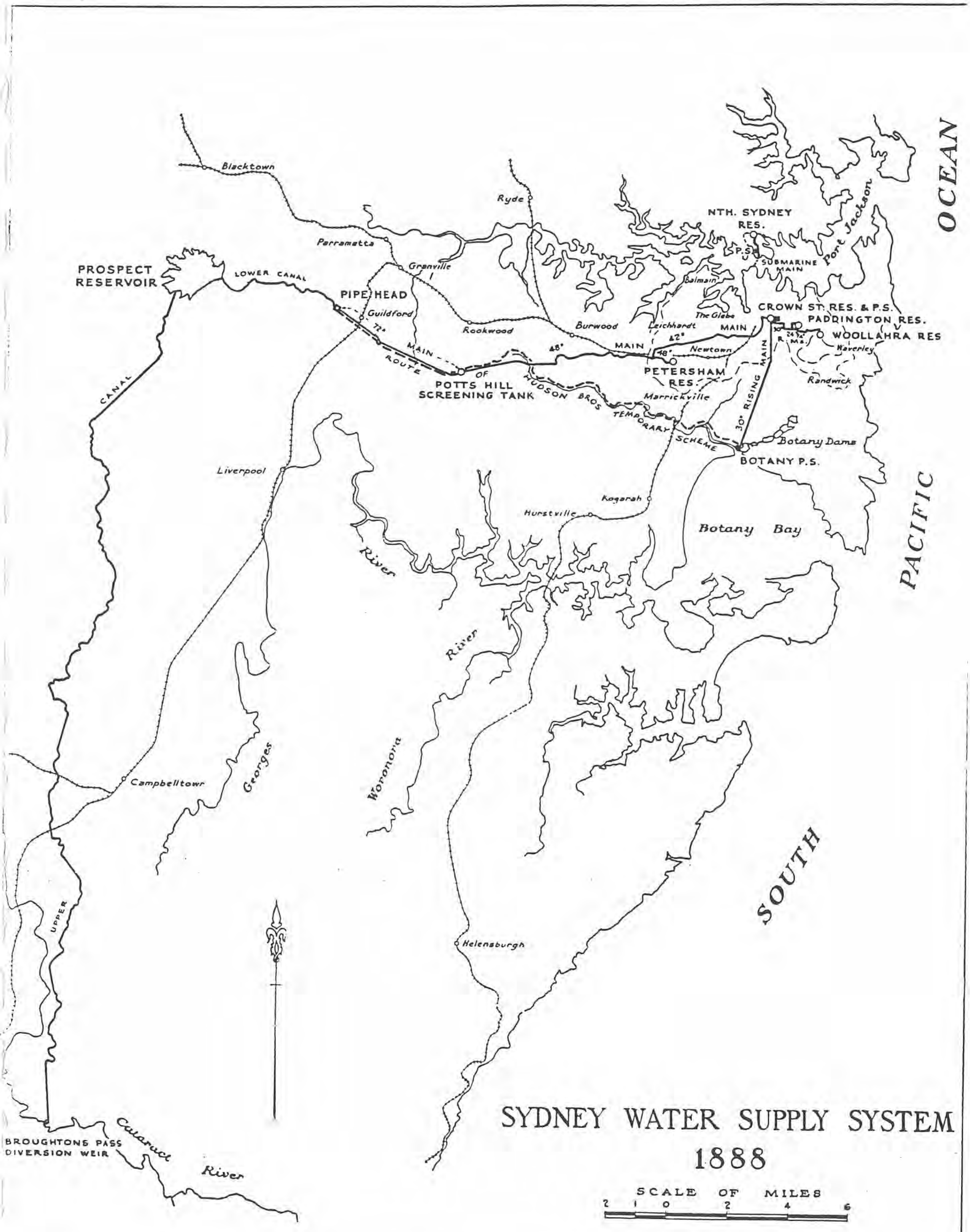
3. The Lower Canal, conveying the water towards Sydney.

Each is a surviving part of the original stage of the Upper Nepean Water Supply Scheme completed in 1889, and each continues to perform its design function, albeit for a limited number of years to come.

It is proposed that the cost of the three plaques be shared, one as is customary by the National Committee for Engineering Heritage, one by Sydney Division and one by the Water Board.

SUMMARY

The attached 1888 map shows the location of the Prospect Reservoir relative to Sydney. The site proved to be well chosen for the future growth of Sydney north and south of the harbour, and for the western suburbs as far as Penrith.



SYDNEY WATER SUPPLY SYSTEM
1888

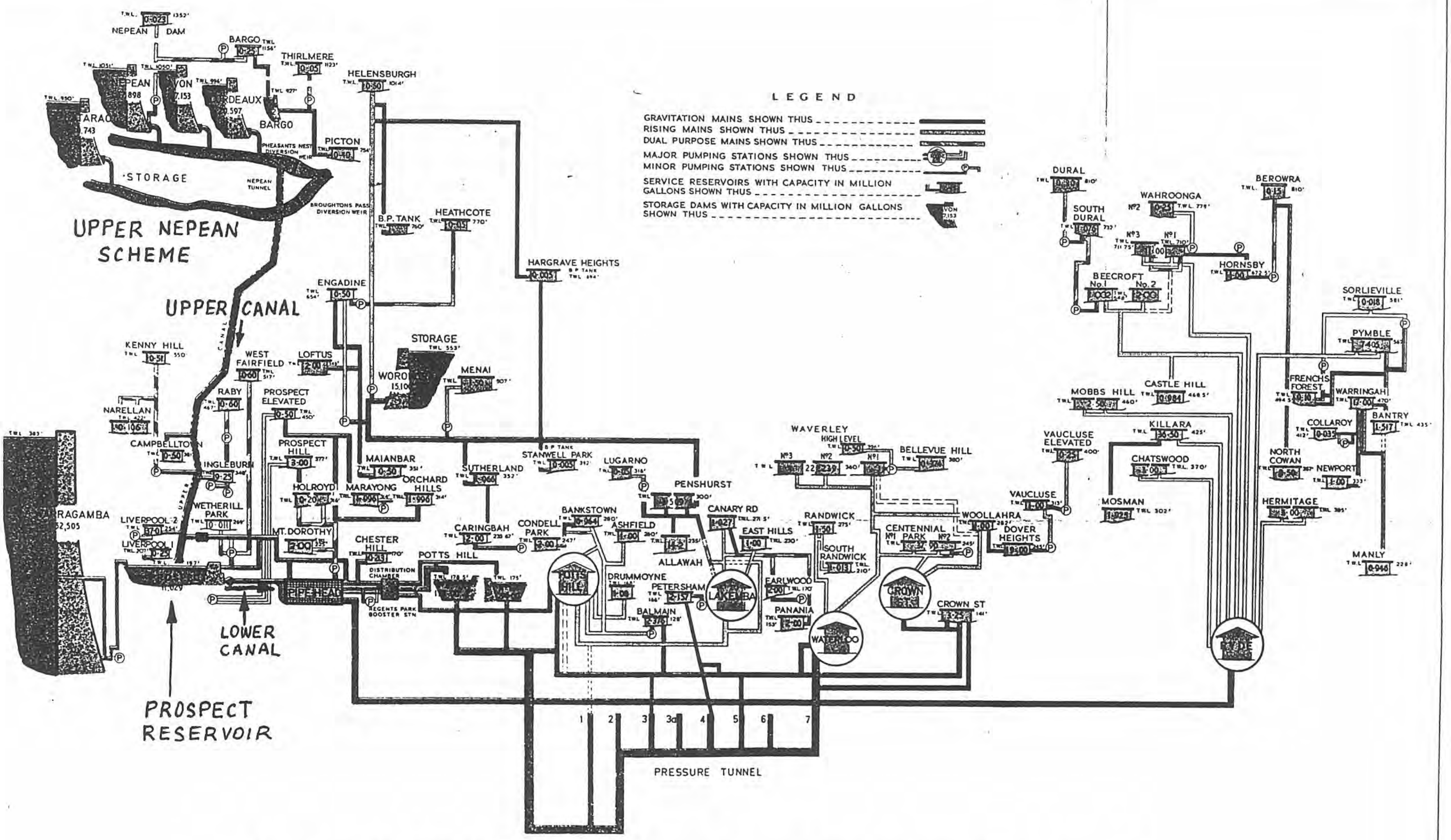


DIAGRAM OF METROPOLITAN WATER SUPPLY SYSTEM

Also attached is a drawing of the distribution system which highlights the key role that Prospect Resevoir plays in Sydney's water supply. The fully developed Upper Nepean Scheme of 1935 (Cataract, Cordeaux, Avon and Nepean dams) delivers water to Prospect via the Upper Canal, and some of the water from the Warragamba, completed in 1959, discharges into Prospect Reservoir via a pipeline. The recently completed Shoalhaven Scheme is also connected to this principal distribution point.

Originally, gravitation mains supplied the city and its inner suburbs with water, but as the urban sprawl progressively occupied higher ground, a series of pumping stations were built with rising mains to these regions.

At its peak, in excess of 80% of Sydney's water used to pass through Prospect Reservoir. In recent years, however, water quality problems and other operational matters have led to changes in the network. The reservoir will soon be bypassed and used only as a large off-line storage reservoir.

The result of the changes will mean that the cleaner water from the Warragamba and Upper Nepean protected catchments will feed directly into a new treatment plant, then into the distribution without ponding. Differences in supply and demand will be balanced by the Prospect storage.

There are in fact long-term plans that the complex may be isolated from the water supply system and given over to recreational uses and historical displays.

In order to place the Prospect Reservoir Complex in its historical perspective, a copy of part of Noel Thorpe's chapter in *SYDNEY - FROM SETTLEMENT TO CITY* is attached. Noel was the archivist - historian for the Water Board for many years and has made a significant contribution to the work and ideals of engineering heritage.

Noel pays tribute to Edward Orpen Moriarty as the master planner of the Upper Nepean Scheme and the Prospect Complex, therefore a biography of this distinguished colonial engineer follows the book extract.

Then, as a social history diversion, some notes about the trout farm at Prospect conclude the Overview.

WATER SUPPLY AND SEWERAGE

by Noel Thorpe

INTRODUCTION

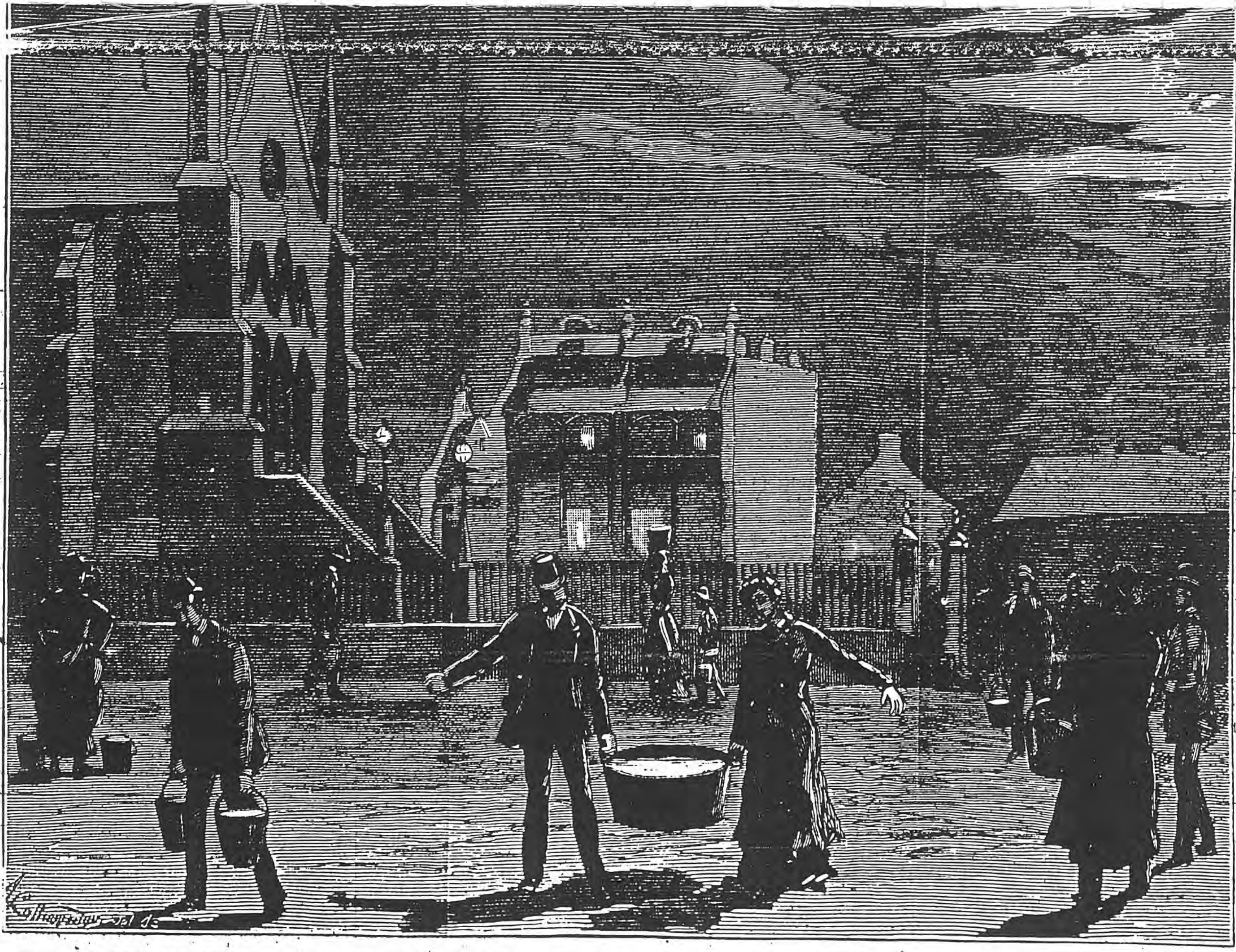
PEOPLE take for granted that they can turn on a tap and water flows. They flush toilets and the waste just disappears. The social impact of those two simple actions, particularly in terms of community health, has been enormous. Few people are aware of how the water is delivered and how wastes are carried away or that a large engineering effort during the past 130 years, involving dams, canals, pipelines, pumping stations, reservoirs and treatment works, has been necessary to make it possible.

The clean, easy-to-live-with conditions of today contrast dramatically with those of the colonial period and, in terms of sewage disposal, the not-so-distant past. During the second half of the nineteenth century, apart from the Sydney city area, there was a negligible amount of water reticulation in the surrounding suburbs. Residents relied on wells, often sunk in their own backyards, on runoff from roofs collected in tanks, and deliveries by water carts. Even when areas were connected to the town water supply, people had to go to conveniently located standpipes to obtain their needs. In dry seasons and in times of drought, an all-too-frequent occurrence, water rationing was introduced and sometimes the flow stopped. As far as sewage disposal was concerned, the standard practice was to use absorption trenches, the pan system, latrines and septic tanks, plus a more sophisticated version of the latter whereby domestic holding tanks were emptied by road tankers.

SEE ATTACHED ETCHING

The relative importance of these two community services had been determined centuries earlier; without water, people died, but with it they could, despite the health risks, survive even the most squalid conditions. Therefore, to secure a permanent clean water supply has always been the first priority and once achieved, the clean-up of wastes could follow. So it has been with Sydney, not quite so clearcut as that, because some important sewerage works were constructed concurrently with water supply projects, but the latter has been dominant right up to the time of completion of Warragamba Dam in 1960.

Domestic water supply was achieved well ahead of domestic sewer connections, consequently this review of the engineering contributions to Sydney's growth, through water supply and sewerage services, will deal with the topics in that order, separately. The water supply story starts with the Botany Swamps Scheme in the late 1850s, and the story of sewage disposal will begin with the Botany Sewage Farm of 1886.



THE WATER FAMINE IN THE SYDNEY SUBURBS.—MOONLIGHT SCENE IN WOOLLAHRA.

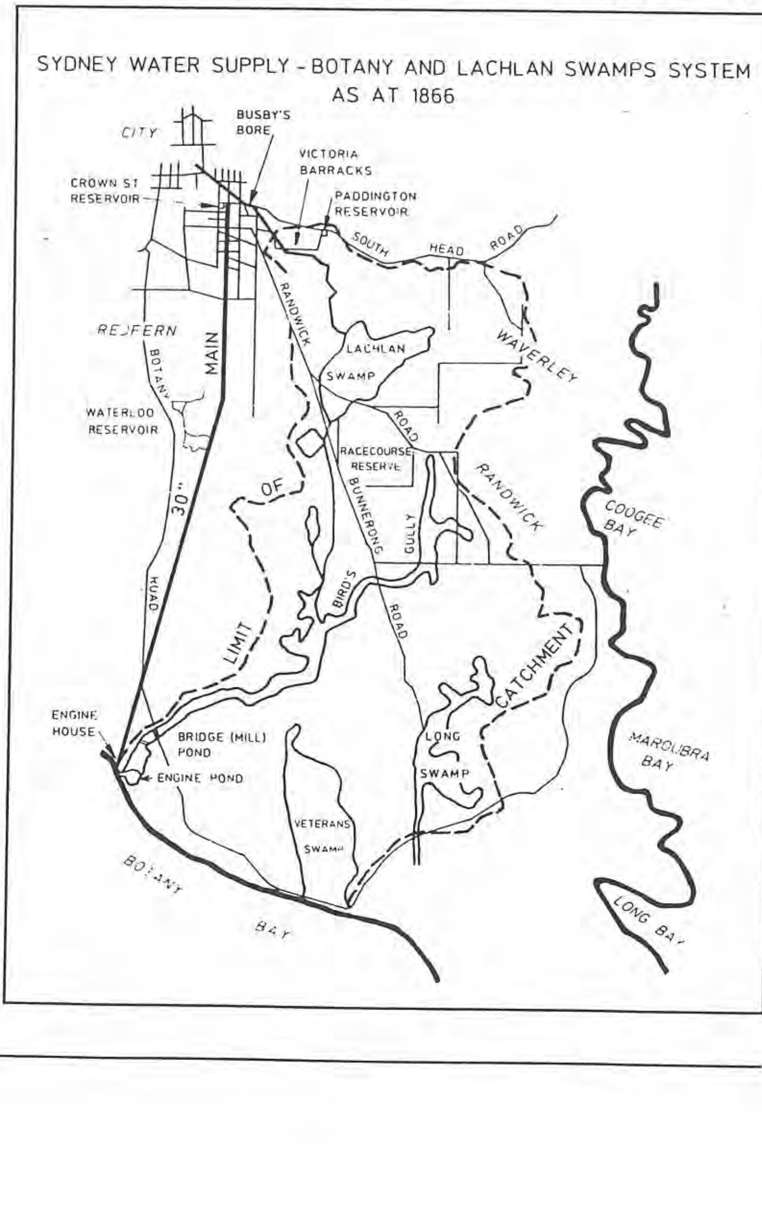
SYDNEY ILLUSTRATED NEWS 4 SEPTEMBER 1880

WATER SOURCES

THE BOTANY SWAMPS SCHEME

The first action of the City Commissioners in 1854 was to improve the water supply via Busby's Bore by establishing a small pumping engine on the Randwick (Alison) Road and pumping part of the low-level flow from the Lachlan Swamps (Centennial Park) across to the mouth of a tunnel near the Showground. This was the first use of steam pumpage in New South Wales, but a more substantial augmentation was required to meet Sydney's needs.

While W B Rider had been Engineer of the former City Council, he prepared designs for a pumpage scheme from Lord's dams, Botany, involving three beam engines driving pumps for delivering water to a mid-level reservoir in Crown Street, Darlinghurst, with a branch main for a future high-level reservoir in the vicinity of Victoria Barracks at Paddington, but his designs, particularly at the Botany end, were over-elaborate and expensive. Discord developed between him and the Commissioners, not only over his water schemes but his sewerage plans also, and



The Lachlan Swamps (Centennial Park) are the northern head of a series of freshwater ponds all the way south to Botany Bay. Present day Eastlakes and The Lakes golf courses and the Mill Pond, Mascot, are remnants of the system. In the 1850s, the southern end was virtually virgin land, known as the Botany Swamps, and its large reserves of good water became Sydney's second source. (Water Board)

he was dismissed in 1855 to be succeeded by Edward Bell, an Englishman of some technical competence. He was able to advise Homersham, the Commissioner's agent and inspecting engineer in England, the duty required of the system, namely that each engine and pump was to deliver 1.5 million gallons per day against a head of 210 feet, and he made one important basic alteration to the designs, substituting pressure vessels for balancing the head for each pump instead of a 220-foot-high standpipe which had been standard English practice up till then. Because of all this bungling, the Botany water supply did not become operational until November 1859, over eight years after its initial recommendation and five years after work commenced. The scheme was traditionally English.

Before the general advent of the electric telegraph as a means of communication, the method of informing the pumping station attendant that the reservoir was full was very simple. On the highest point of Darlinghurst Hill the branch main to serve the future Paddington reservoir terminated at a spillway. Proof that the branch main and the Crown Street reservoir were full was indicted by water flowing from the branch main into the spillway. The Council had erected a large semaphore signal nearby and the frantic wagging of this told the pumphouse employee, armed with a telescope, that the pumps should be stopped at once.

The water was pumped to Crown Street reservoir via a cast-iron 30-inch main, laid in a nearly direct line, the pipes of which had 2-inch-thick walls and the joints were turned and bored interference fits. Portions of this main continued in use until the 1960s. The Crown Street reservoir, which is still in use and likely to be for many years yet, was another piece of classic English design. Of 3.25-million-gallon capacity, it was built partly in excavation and partly on fill. Divided into two equal parts, it is constructed with brick walls faced with impervious glazed bricks to the water line. The roof is of brick jack arches springing from cast iron fish-bellied girders supported by some 170 ironbark columns, 12 inches square, which are generally still in excellent condition. The brick arches are covered by ashes, soil and turf.

Reticulation of water from the Botany scheme was enthusiastically carried out by the City Council and soon the neighbouring councils of The Glebe, Paddington, Redfern, Newtown, Camperdown and Balmain were clamouring for piped water. Occasionally, droughts caused water restrictions but for 25 years there was no absolute shortage.

In the mid-1860s concern began to be expressed that the Botany system would never be adequate for the large metropolis that Sydney was obviously going to become. The large volume of water flowing to the sea down the Nepean-Hawkesbury river system had never gone unnoticed but at the time, its exploitation was beyond the financial and technical resources of the Colony. In 1867 the NSW Government set up a Commission to examine other sources of water as well as the possibility of improving the existing Botany system. The Commission was chaired by Professor John Smith of Sydney University and included in its membership was Edwin Orpen Moriarty, a talented civil engineer of the NSW Public Works Department. During its two years of investigations, a detailed examination of the catchments available to serve Sydney was carried out under the direction of Moriarty. City Council Engineer Bell proposed a massive enlargement of the Botany Swamps scheme through larger storage and additional pumpage capacity and the Commission did recommend a certain amount of amplification of the Botany supply, but concluded that its viability and prospect as a major source of water was limited.

E O Moriarty, born and educated in Britain, used his engineering experience to good effect in New South Wales with river improvement schemes and the master plan for Sydney's water supply.
(Government Printer)

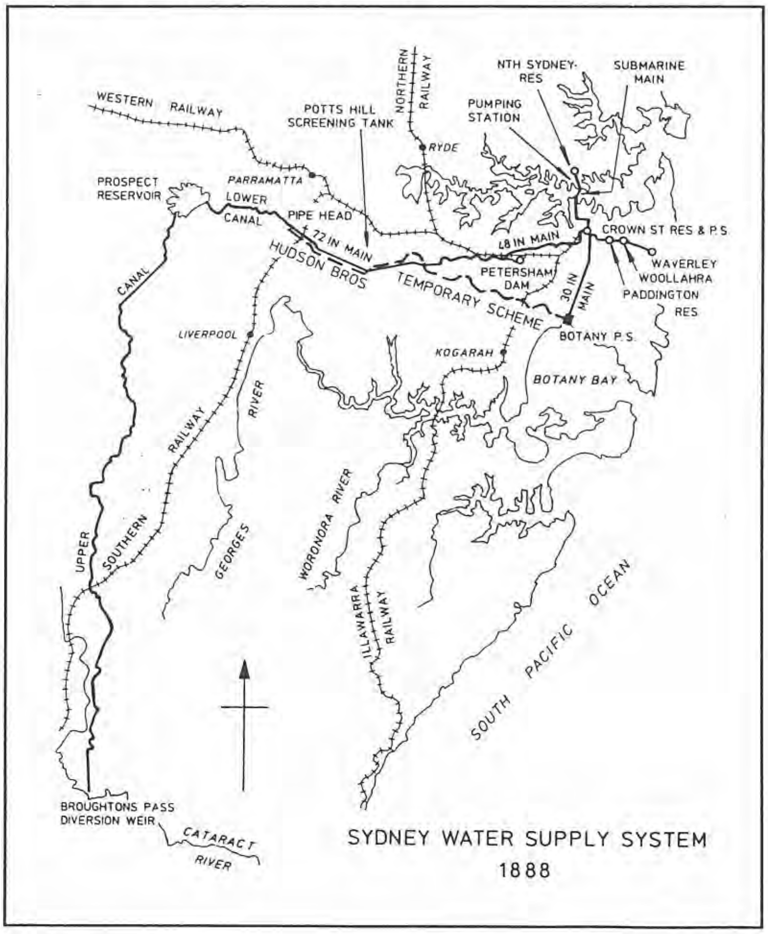
THE UPPER NEPEAN SCHEME

Numerous schemes were investigated by the Commission involving supplies from the Georges River, the Picton Lakes, the Lower Nepean and, the Upper Nepean with its major tributaries, the Cataract, Cordeaux and Avon Rivers. It was this latter scheme, devised by Moriarty, of diverting the flow of the four rivers, high up in the sandstone plateau inland from the Illawarra escarpment, to Sydney via a system of tunnels, aqueducts, canals and pipelines, that received approval. In principle it was modelled on similar schemes elsewhere in the Western world but the sheer size and the audacious engineering effort required to construct it, in an outpost colony not yet 100 years old, made it an outstanding proposal. The scheme captured the imagination of the populace. It promised an almost unlimited supply, for the then foreseeable future, of water pure beyond the imagination of the users of the Busby's Bore and Botany supplies which were becoming contaminated due to the progressive encroachment of urban and industrial developments on the catchment.

J M Smail MInstCE transferred from PWD in 1894 to become the Water Board's Engineer-in Chief. He served until 1920. (Cyclopedia of New South Wales 1907)

Financing the scheme, however, was another matter and it took the findings and recommendations of another Commission, the 1875 Special Board of Health, to jolt Parliament into passing the necessary legislation to implement both the construction of the Upper Nepean water supply system and the genesis of the present system of major sewers for the improvement of sanitation in metropolitan Sydney. In 1879 and 1880 the necessary Acts were passed authorising the construction of the Sydney Water Supply and the Northern (Bondi) and Southern (Botany) Ocean Outfall Sewers. A complementary Act also legislated for an independent Board of Water Supply and Sewerage to control and maintain these works after their design and construction by the Public Works Department. With the institution of these major water supply and sewerage schemes designed by professional civil engineers and subject only to the constraints of available Government finance, a new era of engineering activity, previously dominated by the railways, commenced. The Upper Nepean Scheme, as constructed, brought water from the Cataract River at Broughtons Pass to the Crown Street reservoir, a distance of 63.25 miles. All work was carried out by contract under the supervision of section engineers responsible to the Resident Engineer who was reponsible to E O Moriarty.

However, before the scheme was completed a severe drought affected the Sydney area and early in 1885 fears were expressed that the Botany supply would fail. The major unfinished works in the Upper Nepean Scheme were the wrought iron aqueducts of the Upper Canal, Prospect Dam, the 72-inch pipeline from Pipe Head, Guildford, to Potts Hill and the composite 48/42-inch main from Potts Hill to Crown



The Upper Nepean Scheme involved 15 tunnels totalling 11 miles, 33 miles of canals, and 17 miles of pipelines, plus the building of a major earthern dam with a puddled clay core to form Prospect Reservoir. The diagram also shows the route of Hudson's temporary scheme linking Pipe Head to the Botany Pumping Station. (Water Board)

Street reservoir. During the public agitation for an urgent solution, the general engineering firm of Hudson Brothers (later Clyde Engineering) came forward with a daring rescue plan. It involved (a) substituting inverted siphons, made from cast-iron 30-inch pipes, for the missing aqueducts (b) laying a similar main across the floor of Prospect Reservoir (c) constructing an elevated flume in corrugated iron, on hydraulic grade, from the lower end of the Lower Canal to Campbells Hill south east of Guildford (d) a 30-inch main from there to Potts Hill and (e) a pipeline, of various types of pipes, along the the Cooks River valley discharging into the Engine Pond at Botany, thence by the existing system to Crown Street reservoir. It was a circuitous route but very effective and easy to build. Work commenced on this emergency scheme in July 1885 and water flowed into the Botany Engine Pond in January 1886. The ingenuity and expediency displayed in this scheme were tributes to the resourcefulness and innovativeness that was beginning to appear among Australian engineers cut off as they were from developments and quick responses overseas.

C W Darley, MInstCE, President 1892-1896, was Engineer-in-Chief Harbours and Rivers PWD when appointed. Resigned to become Engineer-in-Chief PWD. (Water Board)

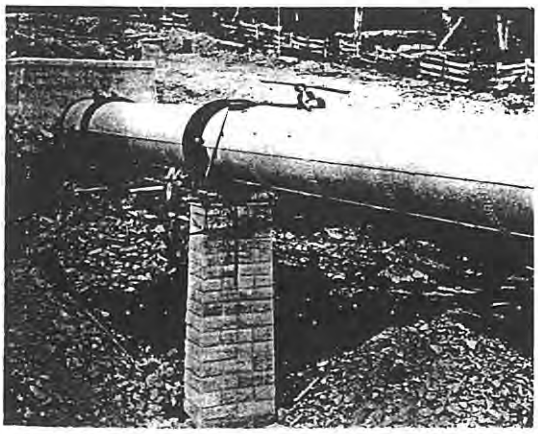
With the completion of the first stage proper of the Upper Nepean Scheme early in 1888, the Board of Water Supply and Sewerage came into being in April of that year. Its function was to maintain the major works completed by the Public Works Department, and to extend and amplify the reticulation system. This dual control, from planning to operation, continued until 1924 when the Metropolitan Water, Sewerage and Drainage Act provided for the Board to be the sole designer, constructor and operator of all water and sewerage works within the Board's proclaimed area of responsibility. But during the intervening 35 years, a number of major works were completed by both Public Works and Board engineers and staffs.

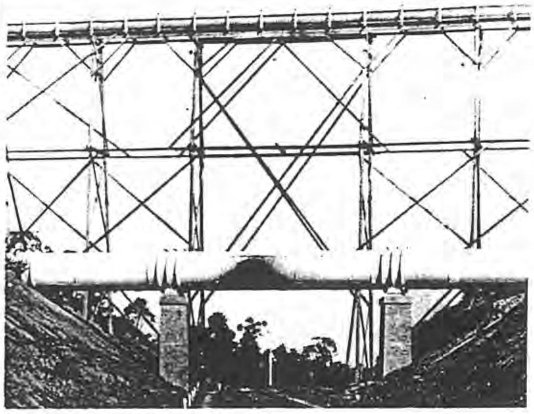
The Upper Nepean Scheme, however, was not immune from the effects of droughts, as exemplified by the severe 1899-1903 drought when the water level in Prospect Reservoir became critically low. Again an emergency plan was instigated. A pumping station, consisting of nine pumps driven by steam engines, was built alongside the outlet basin for lifting water from the reservoir into a flume on the roof of the station. The flume discharged into the Lower Canal adjacent the outlet basin. Another contingency work was the building of a steam-driven electricity-generating station at Menangle Railway Station, which powered an isolated pumping station in the nearby Nepean Gorge, thereby lifting water from the Nepean River into the Upper Canal. A third proposal was to have been a pumping station on the same river near Penrith, powered by the then-newly-developed Parsons steam turbines. Two of these were imported by the Board in 1903, the year the drought broke, but did not go into service until 1908 when they were installed in the Ryde Pumping Station.

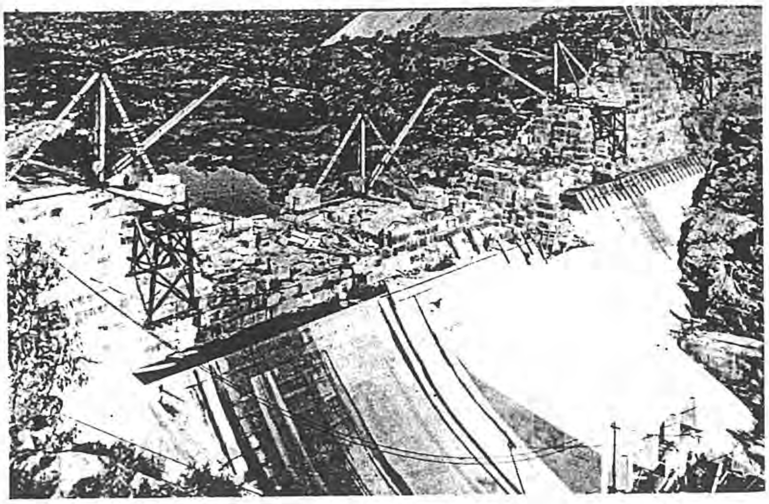
The severity of the drought had demonstrated to the urban population what the country people had long experienced, the fickleness of Australian rainfall. In order to alleviate the effects of future droughts, a long-term plan was decided upon

BELOW LEFT
This 8-foot-3-inch-diameter riveted wrought-iron aqueduct formed part of the Upper Canal and was completed in 1885. (Water Board)

BELOW RIGHT
Hudson's temporary flume and the 1886 replacement 6-foot-pipe aqueduct pass over the Southern Railway near Guildford. (Water Board)







Cataract Dam was constructed in cyclopean masonry, large roughly-dressed sandstone blocks embedded in a sandstone-concrete mortar matrix and faced with sandstone-concrete. Cordeaux, Avon and Nepean Dams were of similar construction, whereas Woronora Dam was commenced in sandstone cyclopean masonry but completed in mass sandstone-concrete. Warragamba Dam was constructed entirely in mass river-gravel concrete. (Water Board)

whereby four large storage dams were to be built on the tributaries of the Upper Nepean. The plan was later expanded to include the Woronora and Warragamba Dams.

In 1903 the Public Works Department began construction of Cataract Dam, the first of the storage dams. In common with nearly all major constructions up till then the work was carried out by contract labour, Messers Lane & Peters being the contractors. The subsequent five major dams of the Sydney supply system, Cordeaux, Avon, Nepean, Woronora and Warragamba, were all built by day labour; Cordeaux and Avon completely by the PWD; Nepean commenced by the PWD and completed by the Board; Woronora and Warragamba by the Board.

Construction of large dams was, at the time, a developing field of engineering design and construction world wide, so there was scope at Cataract Dam, the first of a number of large dams built in New South Wales for domestic and/or irrigation water supplies, for innovative practices. It was the first major civil engineering work to use electricity for the handling and placing of the sandstone "plums" and the concrete, the power being supplied from a specially built power station upstream of the dam site. Steam was raised by burning the timber cut from below the waterline. Logs from such clearance were brought to a works sawmill by a 2-foot-gauge tramway and milled for merchant-grade timber for the above use and other uses on the site. Later, when the dam became somewhat urgent (ironically, not because of drought but due to delays caused by severe flooding) work was carried on into the night by the use of arc lamps hung from the crane jibs. One practice introduced at Cataract but not used elsewhere was the facing of the upstream face of the wall with large concrete blocks. These were cast on a production line that predated many other concrete units manufactured on a mass-production basis.

T W Keele, MInstCE was Chief Engineer for Harbours and Rivers, 1900-03, President of the Water Board, 1904-08, and Commissioner of the Sydney Harbour Trust, 1908-1922. (Water Board)

When the reconstituted Water Board took over in April 1925, the Cordeaux and Avon Dams were well under construction so they were completed by the PWD and handed over to the Board in 1926 and in 1928 respectively. The PWD had also commenced construction of the Nepean Dam, as recommended by the Special Board of Experts (1918-20), but the Water Board assumed control on September 1 1928 and completed the project in 1935.

The Woronora Dam near Sutherland, although not part of the Upper Nepean Scheme, was one of that group of five dams originating from the 1902 drought. It was also recommended by the Board of Experts and was designed as an overshot weir 60 feet high by the engineers taken over by the Water Board in January 1927. The design was amended in 1929 to a dam 200 feet high, but financial stringency, brought about by the Great Depression, resulted in curtailment of the work to a wall only 45 feet high in November 1931. Work restarted in November 1935 with the dam built in mass concrete instead of cyclopean masonry. It was completed in 1941.

SYDNEY

FROM SETTLEMENT TO CITY

An engineering history of Sydney

Edited by Don Fraser

Engineering Heritage Committee, Sydney Division,
the Institution of Engineers, Australia

Engineers Australia Pty Limited

EDWARD ORPEN MORIARTY

ENGINEER-IN-CHIEF, HARBOURS AND RIVERS 1858-1888

The senior civil engineering branch in the Public Works Department is the group now known as Coastal and Rivers, comprising the Coastal Engineering and Rivers and Ports Branches.

Created in 1858, it was then known as Harbours and Rivers Navigation Branch. The engineer chosen to lead the new organisation was Edward Orpen Moriarty, who was well-established in private practice in Sydney.

Born on 11th October 1824 in County Kerry, Moriarty was educated at Trinity College, Dublin, where he graduated BA and MA. He was elected to membership of the Institution of Civil Engineers in 1865.

Moriarty's first position was as a cadet on the construction of a breakwater on the Isle of Portland. He then became an articled pupil of Mr. William Morgan (inventor of the feathering float for paddle steamers) of Acraman, Morgan and Company, of Bristol. While serving his indentures, he worked on the design and construction of steamships of the highest class. He was next employed under Sir John Macneill on the layout and construction of railways in Ireland. During that period he passed the prescribed examination for County Surveyor under the Board of Works.

In 1848 he came to Sydney, where his family had settled in 1843. His father, Merion Marshall Moriarty, was Port Master in NSW and Harbour Master in Sydney, and his brother Abraham was a clerk in the Lands Department.

Finding no immediate opening in his profession, Moriarty accepted a position in the Lands Department as assistant surveyor, and was employed for some time on the geodetic survey of the Darling Downs and adjoining districts. In 1852 he left the Lands Department and returned to Sydney, where he established an engineering practice. Among the works he was engaged on were the supervision of construction of Hunt's Creek Dam (Lake Parramatta), timber bridges over the Murrumbidgee River at Wagga and the Nepean River at Richmond, and the opening and development of coalmines at Wollongong.

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Moriarty's family was strongly marine oriented. His grandfather was Vice-Admiral Sylverius Moriarty, and his father had served in the Royal Navy during the war years 1807 to 1815, as midshipman and lieutenant, at Copenhagen and on the Mediterranean and West Indies stations. Later he commanded Irish Channel steamers on the Cork-Bristol run. Moriarty's strong interest in marine matters was responsible for his next Government position.

Still in its infancy in the early 1850's, marine steam power brought with it a series of accidents and disasters caused by defective steam machinery. Because of his marine engineering experience, Moriarty was acutely aware of the hazards of steam power, and he convinced the Government of the necessity for an efficient inspection system to prevent such incidents.

As a result, in 1853 he was appointed Engineer/Surveyor to the Steam Navigation Board (of which his father was a member). He carried out this office until 1858. In April 1861 he became President of the Board, relinquishing the position in March, 1872, due to the pressure of other work.

In the early 1850's the port facilities at Newcastle were not adequate to service the increasing volume of coastal and overseas shipping. The Government responded by appointing Moriarty to the new position of Superintendent of Improvements to the Navigation of the Hunter River, on 23rd November 1855.

The first record of his activities in this field appears in the Government Gazette of 17th March 1857, when he called tenders for the supply and deposit in barriers of stone ballast at the River Hunter. The advertisement appeared over the address, "E. O. Moriarty, Engineer to the Newcastle Harbour Works, 25 Pitt Street". The altered title was presumably more manageable than the official one. In September, 1857, he called tenders for a new steam dredge for the Hunter River. (The only dredge in NSW at that time was "Hercules", which had been operating in Sydney Harbour since 1843.)

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The major work on which Moriarty was engaged from 1855 to 1858 was the observation of the Hunter River and development of a plan to control the sea entrance by extended breakwaters and the river channels by stone training walls. This plan produced the shape of today's port.

By January 1858, Moriarty had moved his office to 33 Hunter Street, from which he called further tenders for machinery and mud barges for the new Hunter dredge, and a new bucket frame or ladder for "Hercules". Tenders were also called for a new wharf at Newcastle.

Meanwhile, representative government had been granted to New South Wales in 1855, and the first departments of the new government were created in 1856. Lands and Public Works were grouped in one portfolio under Parliamentary Secretary Terence Murray, although they remained separate organisations at different locations. The initial Public Works Branches were Railways, Electric Telegraph, Roads, Harbours and Rivers Navigation, Cockatoo Island Dry Dock, and Colonial Architect.

Moriarty was the obvious choice to lead the Harbours and Rivers Navigation Branch, and he was appointed Engineer-in-Chief on 10th October, 1858 (the day before his 34th birthday), and remained in that position until his retirement in 1888. In the first year of operation he had a staff of five, and Branch expenditure was less than £15,000. By 1888, the staff had grown to 107, and expenditure to £436,000.

In the beginning, the Branch was responsible for these activities:-

Construction and maintenance of dredge plant and equipment
Dredging operations in NSW
Circular Quay improvements
River improvements (coastal and inland)
Sydney Harbour Foreshores Land Reclamation
Coastal and inland wharves and jetties - construction and maintenance
River crossing punts - construction and operation until 1872
Sydney Harbour Upper Reaches Crossing Punts
Newcastle Harbour Wharves
Newcastle Harbour Improvements
Maintenance of Liverpool, Parramatta and Cook's River Dams
Cockatoo Dockyard.

From 1875 to 1878, the Branch designed and constructed Sydney's sewers and stormwater drains; this function was taken over by the new Sewerage Construction Branch in 1879.

The Harbours and Rivers Branch started on surveys for water supplies for Sydney, Newcastle and Maitland in 1878, and began the survey and construction of country towns water supplies in 1879, at which time Moriarty also became responsible for the design and construction of Sydney's water supply.

At the end of this article, you will find a short list of works which is worth studying, as it will give you some idea of the extent of Harbours and Rivers Branch operations during Moriarty's 30 years of leadership.

Four areas deserve special mention - dredging, Moriarty's Wall, Trial Bay Prison and Breakwater, and the Upper Nepean Scheme.

Dredging

In 1858, Moriarty had two dredges, "Hercules" and "Hunter", which were still under construction. At that time, the only dredging operations were in Sydney Harbour. By 1888, he had built a further 31 dredges, 15 tugs, 6 steam launches, a large number of punts and associated plant, and was dredging all of the harbours and coastal rivers of NSW.

Moriarty's Wall

The first steamship to enter the Clarence River was the "William the Fourth" (the "Billy") which negotiated the bar in 1839. Incidentally, the "Billy" was the first coastal steamer wholly built in Australia. As grazing, agriculture and dairying developed in the region, strong pressure built up for entrance training works. In 1860 the river entrance was characterised by a sandspit which confined the channel to a width of 750 feet against the Yamba foreshore.

In that year Moriarty proposed a scheme to stabilise the location of the entrance of the Clarence River. His plan involved the construction of a training wall fronting the southern foreshore at Yamba, a southern

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breakwater projecting from Yamba headland, and a section of training wall on the northern (Iluka) side.

Work started on the southern training wall in 1862, using stone quarried at Pilot Hill, Iluka. The first Resident Engineer was W. H. Baron, assisted by G. V. James. Construction of the northern training wall began in 1873, under Assistant Engineer Edward Bell. In October, 1874, Bell was replaced by Assistant Engineer Merion H. Moriarty, one of E. O. Moriarty's brothers. Merion supervised the project until 1880.

A series of floods between 1860 and 1880 breached the sand spit and greatly altered the shoreline, necessitating redesign of the northern training works. Work on the northern training wall was abandoned in 1889 when a new scheme proposed by Sir John Coode, an eminent English consulting engineer, was approved. Sections of Moriarty's scheme were dismantled, and the rock was used in the construction of the northern training walls of Coode's scheme.

When work ceased in 1903, Coode's internal training walls had been fully constructed, and only a small spur of Moriarty's wall remained.

In 1950, the Clarence Harbour Works Act authorised extension of the southern breakwater, construction of a northern breakwater, removal of a submerged reef and Moriarty's wall, and dredging of a navigable channel. The breakwaters were completed in 1971. Removal of the reef and the dredging were not carried out, but the remaining spur of Moriarty's wall was rebuilt to improve the training of tidal flows into the main channel.

Trial Bay Gaol and Breakwater

In the 1860's, sea travellers faced many dangers on coastal voyages in NSW. Sudden gales were a special hazard. Between Port Stephens and Moreton Bay, a distance of 380 miles, only Trial Bay was reasonably safe, and then only during southerly gales. In a sou'-easter it was useless.

Moriarty was asked in 1863 to report on the possibility of making a harbour in Trial Bay, where ships could shelter in rough weather. His surveyor, W. H. Baron, had carried out a limited survey of the bay in 1861,

with very few soundings in the proposed breakwater area. Moriarty's report of 1866 was based on that information. The report suggested that a harbour could be constructed by building a stone breakwater projecting 5,000 feet from Laggers Point.

The annual shipwreck reports showed heavy losses of life and property. Between 1863 and 1866 ten steamships and seventy-nine sailing ships were lost, with 243 people drowned. The impact of these disasters moved the Government, in 1870, to allocate £10,000 towards the proposed Trial Bay Harbour. Parliamentary support was not unanimous. Some members viewed the scheme as impracticable or excessively costly. However, there was strong support from the people of the Macleay River Valley, who were anxious to see the harbour proceed for its transport possibilities.

Meanwhile, various ideas for penal reform were under discussion. A Prisons official, Harold Maclean, visited England in 1869 to inspect British prisons. On his return, he included in his report a recommendatic that a Public Works Prison, using the labour of long sentence prisoners, should be established.

When Maclean became Comptroller-General of Prisons in 1874, he pressed for a Public Works Prison. Trial Bay appealed to him as an appropriate location. The following year he and Moriarty proposed the use of prison labour to quarry stone and to work on the proposed breakwate The Government then allocated further funds for the harbour project and a gaol for the prisoners.

Several proposals for gaol accommodation were put forward. Moriart suggested the use of hulks in the bay. Maclean suggested a wall across Laggers Point with timber buildings inside the boundary. Another plan was a timber gaol within an 18 foot high wall. None of these schemes was accepted.

Finally, a plan prepared in 1876 was approved. The prison was to be built of local granite. It was to consist of a central hall and a two-strong cell block, enclosed by a high stone wall with four watchtowers

.../7

The contractor, D. Macquarie of Sydney, began work on the gaol in 1877, under the supervision of Resident Engineer C. S. Brownrigg. The gaol was ready to receive prisoners in March, 1886, but work on the breakwater did not begin until 1889, after Moriarty's retirement.

In 1890, C. W. Darley, Moriarty's successor, estimated that it would cost £280,000 and 35 years of prison labour to complete the breakwater to a length of 4,950 feet. However, heavy storms in 1892, 1893 and 1897 had destroyed a great deal of the work, requiring repeated rebuilding.

At the end of 1902, the breakwater was 981 feet long, but a great storm that year demolished much of the completed work. In addition, shoaling in the bay was so bad that it was difficult to use the gaol wharf. The need for a harbour of refuge had been reduced by the improved seaworthiness of the more modern vessels operating on the coast.

In 1903 the authorities decided that the prison did not fit in with modern ideas of penology, and it was closed in that year. Work on the breakwater was discontinued.

<u>The Upper Nepean Scheme</u>

The Upper Nepean Scheme was Moriarty's greatest work. His involvement began in 1869, when he was a member of the Royal Commission on Sydney's Water Supply, which recommended adoption of that scheme. After some delay and further consideration, the Appropriation Act was passed in 1879, and the Harbours and Rivers Branch began work on the scheme the following year.

The project involved the construction of:-

A weir across the Upper Nepean River just below the junction of the Avon and Cordeaux Rivers at Pheasant's Nest, with a diversion tunnel to connect with the Cataract River.

A similar weir across the Cataract River at Broughton's Pass, from which the waters of the four streams were diverted into a 36-mile conduit (the Upper Canal), consisting of a series of tunnels, open canals and aqueducts.

A 1,951 million gallon storage reservoir at Prospect.

A five-mile canal (the Lower Canal) from Prospect Reservoir to Guildford (the Pipe Head Reservoir).

A five-mile 6-foot diameter wrought iron pipeline from Guildford to a 96 million gallon service reservoir at Potts Hill, together with a 4-foot cast iron pipeline from that reservoir to the existing reservoir at Crown Street, with a branch to a new 4 million gallon reservoir at Petersham, with additional new reservoirs at Newtown, Woollahra and Waverley.

The total length of the completed work was 63 3/4 miles, including 11 5/8 miles of tunnels, 33 miles of canals, two miles across Prospect Reservoir, half-a-mile of wrought iron flumes 8 foot and 7½ foot diameter, 4 7/8 miles of pipe of 6 foot diameter, 7½ miles of 4 foot pipe, and 7½ miles of 3½ foot diameter cast iron pipe. The work was completed in 1888 at a cost of £2,076,313. A bronze plaque was placed on the outlet valve at Prospect in 1910 to commemorate Moriarty's association with the scheme, which is a fitting memorial to one of the Department's eminent engineers.

One could be excused for assuming that Moriarty would have been fully engaged in managing the Harbours and Rivers Branch. This was not the case. Although busily occupied as Engineer-in-Chief, Moriarty found time for many other activities. In addition to his departmental duties, he was appointed a Commissioner of the Superannuation Fund in 1865, and the Royal Commission of the Inquiry into Sydney's Water Supply in 1867. He was President of the Hunter River Floods Commission in 1869/70, and was on the Commission on Defence from Foreign Aggression and the Board for Inspecting and Maintaining Colonial Warlike Stores. In 1875 he was appointed a member of the Sewage and Health Board, which was appointed to prepare a scheme of sewerage for Sydney and suburbs.

In 1860/61 he supervised the design and construction of the first (low level) Pyrmont Bridge and associated access works at Blackwattle Swamp (Wentworth Park) for a private company. He provided consultant advice to Victoria on Yan Yean Water Supply, and a water supply from the River Colibar

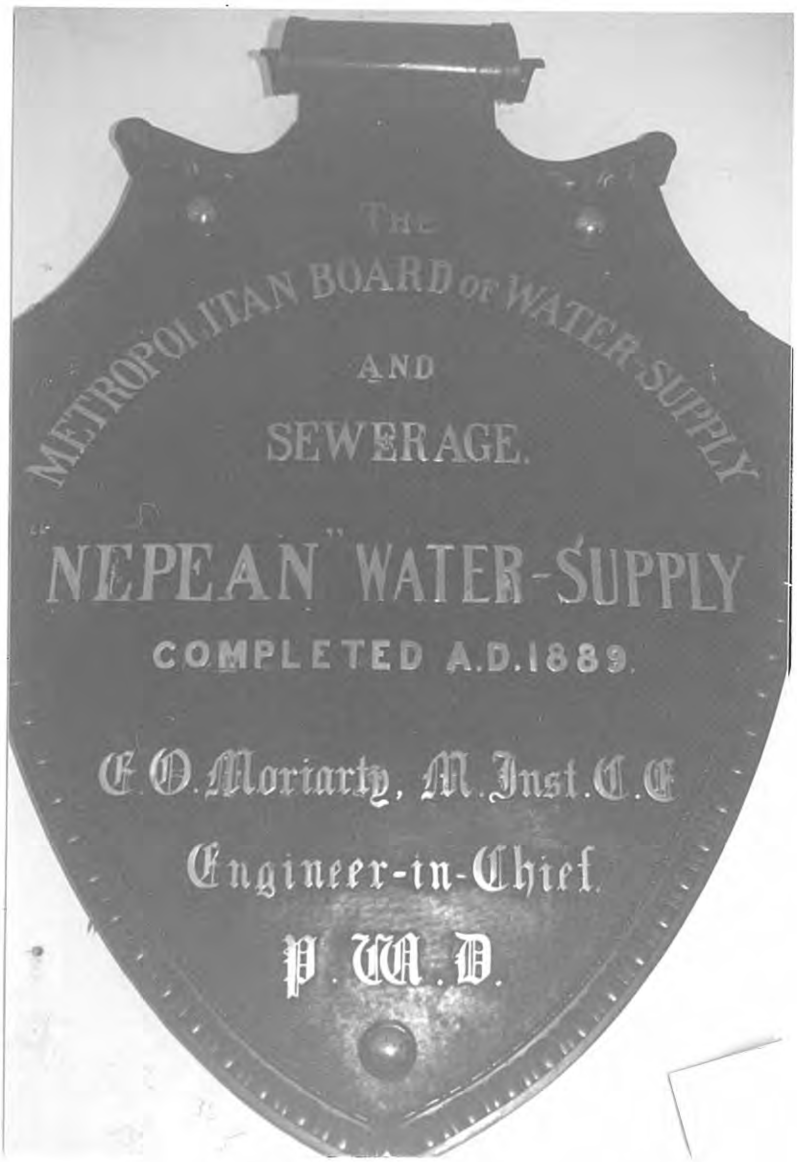
.../9

to the Victorian mining districts. He also advised the New Zealand Government on harbour improvements at Greymouth, and the proposed Auckland water supply in 1874.

In addition, Moriarty was a Councillor of the Philosophical Society, a member of the Linnean Society and of the Royal Sydney Yacht Squadron, and a Captain in the Engineer Corps Volunteer Rifles from 1871-1873.

He retired in 1888 at the age of 63, because of ill-health, said to have been caused by the pressures of the Upper Nepean Scheme. He died in England in 1896.

His portrait in oils hangs in the Chief Engineer's office.



M. Maunsell,
January 1985.

Selected List of Works During E. O. Moriarty's
30 Years as Engineer-in-Chief,
Harbours and Rivers Navigation

LONG TERM WORKS

From	
1861	Newcastle Northern and Southern Breakwaters Wollongong Harbour Improvements Kiama Harbour Construction
1867	Clarence River Improvements, including Moriarty's Wall
1873	Moruya River Improvements
1874	Trial Bay Prison and Breakwater
1880	Upper Nepean Water Supply Works, including Prospect Reservoir

NOTABLE OR INTERESTING WORKS

1858	Gladstone (Qld) Water Supply Newcastle Lighthouse Obelisks (leading marks) Sydney, Newcastle Steam Dredge "Hunter"
1860	Botanic Gardens Seawall
1861	First (low level) Glebe Island Bridge Road/Wharf Twofold Bay Also 1861/66 supervised Pyrmont Bridge (private construction)
1862	Port Stephens Lighthouse Eden Lighthouse Steam Dredge "Pluto", Shoalhaven Cape St George Lighthouse Fort Macquarie Seawall
1863	Cooks River Dam - additional (northern) flood gates

.../2

NOTABLE OR INTERESTING WORKS (cont'd)

From	
1864	Morpeth Coal Shoots Newcastle Coal Basin
1865	Dredge "Vulcan" Darling Island Reclamation and Stone Dyke (Darling Harbour)
1866	Dunmore Bridge, Hunter River Dredge "Pluto" Newcastle Coal Staiths Wollongong Coal Shoots
1868	Pitnacree Bridge, Hunter River Dredge "Samson"
1869	Dredge "Titan"
1870	Darling Harbour Iron Wharf and Steam Cranes Blackwattle Swamp Reclamation (Wentworth Park)
1871	West Maitland Bridge
1872	Ulladulla Wharf and Tramway Wollongong Lighthouse
1873	Liverpool Dam Raising Ulladulla Lighthouse Moruya Northern Breakwater Blue's Point Wharf
1875	Hinton, Hunter River - first steam crossing punt Macquarie Street - continuation and formation (completed 1883) Dredge "Newcastle"

.../3

COPY

3 March, 1982.

To President A. C. Flint of C.A.S.

"HOW TROUT WAS FIRST INTRODUCED INTO AUSTRALIA"

1840-5 20 years of unsuccessful attempts.

1865 The first efforts to establish trout into Australia. The early attempts to import eggs failed for more than 20 years as the long sea voyage from England through the tropics destroyed the eggs on each occasion. And was not until 1865 that the first batch thrown in at the last minute with a consignment of salmon eggs hatched successfully. These eggs were stored in the "Ice House" of the steamship "LINCOLNSHIRE". Although many were destroyed during the voyage, sufficient did hatch, however, to allow the Tasmanian Government to release a few thousand fry into the Derwent River and Great Lake.

1870 Five years later, Mr. John Keys of Muswellbrook successfully imported trout eggs from Ireland, releasing them into the Hunter River. Ash from bushfires destroyed these efforts.

1874 Mr. Keys repeated his releases of fry from eggs from New Zealand and Tasmania.

1888 Dr. J. C. Cox, Commissioner of Fisheries in the Colony, stocked the upland streams of N.S.Wales from fry given him by the Victorian Government, which were liberated into the Shoalhaven, Wollondilly and upper Nepean Rivers. Of the 1,000 fry given to Dr. Cox, some were sent by pack horses up into the Snowy River system.

1894 The first recording of brown trout caught at Delegate, N.S.W. Caught by Mr. Rose, weighing 7 lbs.

Brown Trout

1889 Saw the first hatching of brown trout eggs. They were hatched in the Commissioner's kitchen in Pitt Street, Sydney, and the following 3 years saw 66,000 eggs hatched there before the Commissioner, Dr. J. C. Cox, had the Government establish a
1892 Hatchery at the Prospect Reservoir in 1892.

Rainbow Trout

1896 Rainbow trout eggs were first hatched in N.S.Wales in 1896, and the following season the fry were distributed into the 86 streams of the cooler rivers of the State.

1899 By 1899 the rainbow species had so rapidly multiplied that they out-numbered the brown species.

1903 A closed season introduced from April 7 to August 31st. The takable length was set at 10".

Prospect continued to hatch for the State Fishery receiving eggs from Tasmania, N.Z. and Victoria. To stock the 3,000 river miles of our State's cooler waters.

1914 Saw World War I and interruptions to such work of hatching.

1920-32 The State Hatchery at Prospect operated with mixed success and closed down operations in 1934.

1935-7 Saw registration of Acclimatisation Societies - were then formed to hatch and rear and liberate the fry into the State's waters under the supervision and authority of the State Fisheries Dept.

* * * * * * * * * *

3.3.82

BRIEF HISTORY OF C.A.S.

- A. C. Flint

Following the closure of Prospect Hatchery in 1934 which had operated with mixed success between 1920-32 and at this time Trout Fishing was only then in its infancy, the demand for stocking our rivers steadily grew in the following years and when the Hatchery closed causing concern to the Trout Fisherman, they felt that something had to be done to restock the streams. Thus it so often happens that necessity is often the mother of invention. There just had to be some means whereby the growing number of trout enthusiasts could get fry to replenish their streams for the sport was now growing a pace and the demand for fry of the aristocrat of all fishes. The delectable trout was in a greater demand than ever. The Orange Hatchery came to the rescue but only in a small way.

1935 So it was that two small bands of rod fishermen - one party from Sydney, the other from the Lithgow Trout Fishermen's

1937 Association, met one day in 1937 on the banks of the Duckmaloi River at which meeting these members of the two trout fishermen's clubs formed a body to look into the possibility of operating as a Society to hatch, rear and liberate trout fry for the use of their beloved sport.

The name of this Society was agreed on to be The Central Acclimatisation Society, supported by annual membership fees.

The C.A.Society was accepted by State Fisheries and Registered, thus was born "C.A.S."

1937-8 The requests and plans were soon put before the Fisheries Department with detailed and intentions for operation as a Society, which the Department received with great interest and soon registered the young Society, which was to operate under the direction of the Department. Thus the Central Acclimatisation Society was born.

The young Society was soon to face many great setbacks, as much preparation and planning by only a handful of enthusiasts faced the great task of securing ova and hatching some for liberation.

With very little finance in hand, much voluntary work and effort went into getting a start.

1938 There was a suitable place to be located with correct . . . pH readings and continual water flow, the suitable site for storage dam to consider and reasonable access for transport to and from the area; an area in the higher uplands where the colder streams were located. After much surveying, a site on the Boggy Creek between Hampton and Oberon was chosen. Now the storage dam to be made and area cleared and fenced in. Caretaker's cottage to erect, hatching troughs and feeder traces to the header troughs. Here the Lithgow members did a mighty job. Help came from various people and firms in transporting materials onto the site.

Time was running out for the first efforts for hatching, so got permission to clean up the old Prospect Hatchery to handle the first efforts of hatching, which also took a lot of work but had some success.

FIRST EFFORTS OF HATCHING CARRIED OUT AT THE OLD PROSPECT HATCHERY

1938-9 Interest grew among the public when Branches were organised by the new Society which also helped financially from the membership fees paid.

1939 When all was ready to operate the Boggy Creek Hatchery, war broke out in Europe and Government help, especially with finances, was cut. Once more C.A.S. had to do much work and labour and expenditure from the handful of volunteers. Labour of love and sweat, hundreds of man hours given to get this hatchery going.

1939-40 A slow-down in getting the materials dragged on. Now the Country at war which brought a halt to progress.

Yet little by little the faithful few pushed ahead and when hostilities ceased the work again moved on.

1940-5 A few hatchings took place. After the hatching season the caretaker would leave for the late summer and autumn. This is when vandals broke in and destroyed much of the property of C.A.S. - just another "set back".

1945-6 Mixed success in getting sufficient ova from New Zealand hampered the laying down of ova - as the shipments of eggs were packed in ice and charcoal and some eggs began to show eyed on arrival with many dead white eggs. All this took time to sort out and lay down for hatching. By the time the fingerlings were ready for the various Branches to get and liberate, 50% of the number hatched would have died. Thus the need for a large hatchery was evident as water supply was not sufficient in summer. This was a real problem overlooked in the first place.

Thoughts about a Larger Hatchery

1947 Already the Boggy Creek Hatchery proved far too small for the growing demand by Branch members to stock their rivers. So, more surveying to locate a better water supply had to be sought - for a small Hatchery, Boggy Creek was perfect.

Here it was - yes, right down stream of the big Oberon Dam.

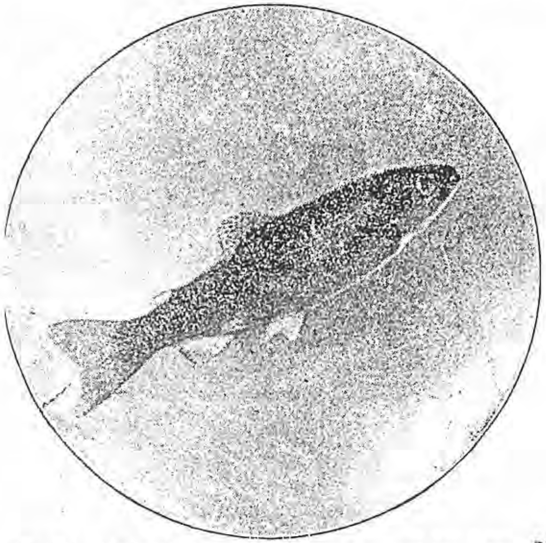
Much planning and designing was drawn up and days even run into weeks getting this dream hatchery started, on paper, etc. Boggy Creek could still continue to help out while the finishing touches to Oberon were completed.

Again a severe blow comes to C.A.S. The Water Board refuses at the last minute to allow the required water flow to operate the size hatchery which we had plans drawn up for.

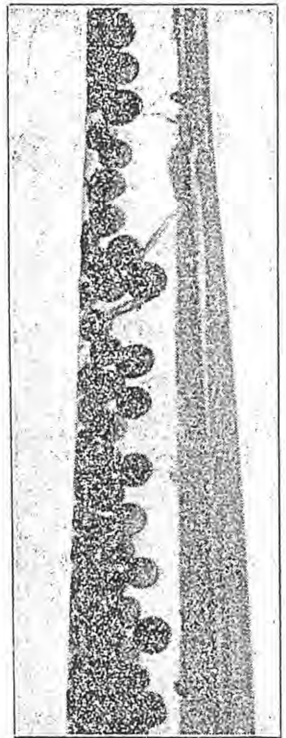
1947 Once again C.A.S. to look for a new site and where there was a constant supply of water all the year around. What better place than under the big Dam at Bunaga, now not in use by any bodies from the days of the mining era which had long ceased.

THE SUN
WEDNESDAY, AUGUST 22, 1923

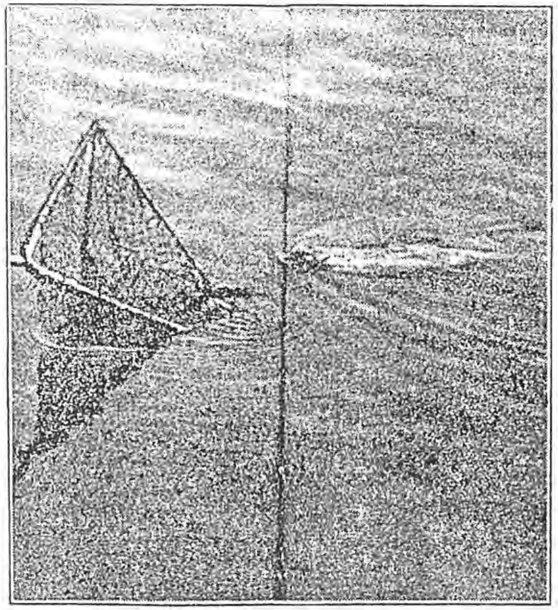
Making Sport for Trout Fishermen— —From Rotorua to the Prosper



A HEALTHY YEARLING.—This rainbow trout has a pond of his own at Prospect. In a few years his offspring will make sport in some country stream.



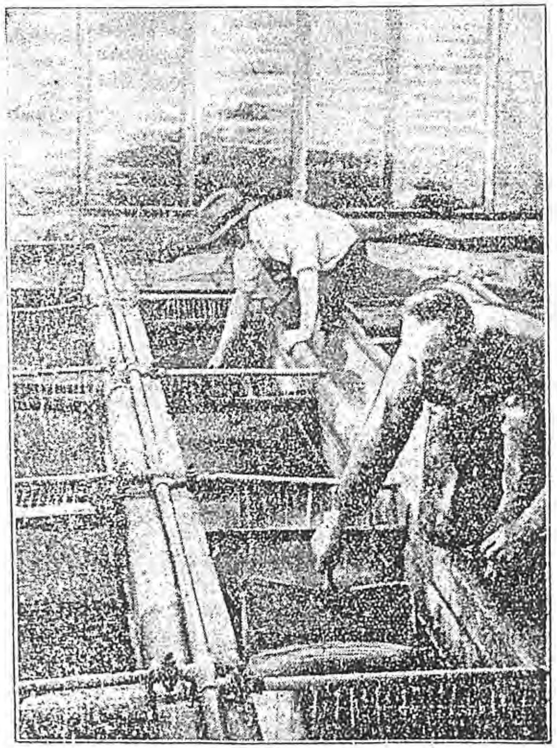
TROUT EGGS.—Note the tails of two little fellows just coming out.



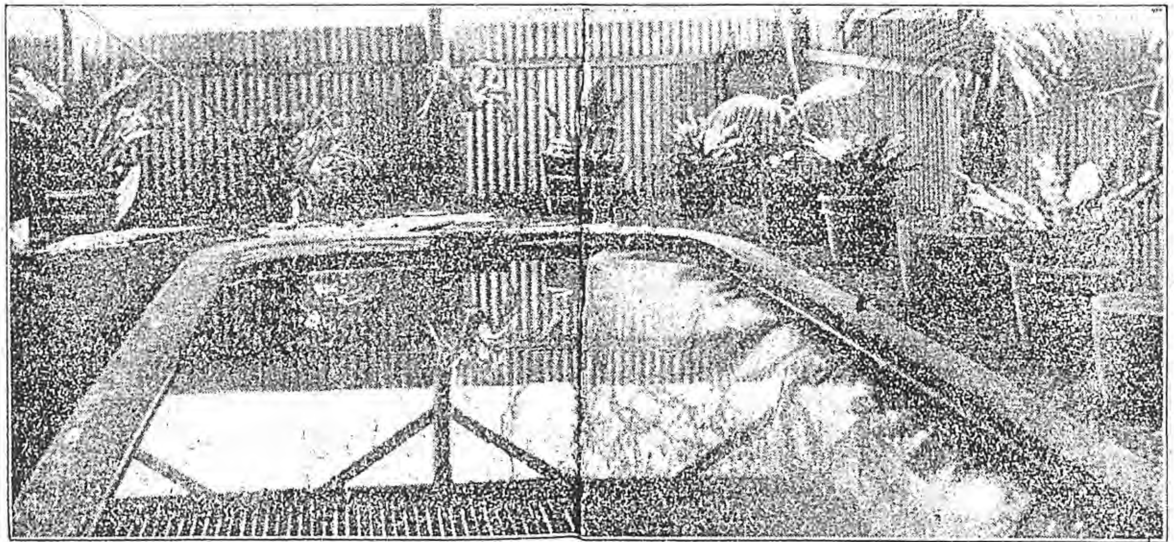
HOW TO LAND A TROUT.—The rod is in the hands of Mr. Anderson, of the Fisheries Department, who holds the championship for casting. See next picture.

MR. ANDERSON lands a "catch" at Prospect. This is how it should be done.

THESE TROUT are a month old. As New Zealand, packed in ice. On Friday in rivers in the west.



INTERIOR OF THE NURSERY.—Taking trout "fry" from the races, in which they have been hatched and bred. They



ONE OF THE FIVE PONDS in which stock trout are kept for breeding. The water is kept running continuously through the ponds. When they are ready to be "stripped" of their eggs the trout are caught with nets. **The article below should be read in**

THE CORRECT WAY to "strip" a tro

THE TROUT OF PROSPECT

(Contributed by John Lawson, based on an article by H.K. Anderson, Inland Fisheries Officer, first published in the Australian Museum Magazine, about 50 years ago.)

Many species of wild-life introduced into Australia have been an unmitigated disaster - notably rabbits, foxes, and even such apparently harmless creatures as sparrows. By contrast, one species seems to have been of great advantage to the community without destroying the environment; this is the trout. Few people are aware of the significant contribution made by Prospect Reservoir to the introduction of trout into New South Wales.

The first mention of trout in New South Wales dates from 1870, when a Mr. John H. Keys, of Muswellbrook, imported trout eggs from Ireland and placed them in the Hunter River. During the next three years he repeated the experiment with eggs obtained from New Zealand and Tasmania.

During the 1880's there were releases by private individuals and also by the Commissioners of Fisheries for New South Wales. The Commissioners released fry (young trout) in the Upper Shoalhaven, Wollondilly, Upper Nepean and Hattai rivers, Picton Lakes etc.

During 1889 the Commissioners obtained five or six thousand trout eggs from the Acclimatisation Society of Geelong (Vic). A large percentage of these eggs hatched, and the fry were released in suitable streams and in Prospect Reservoir.

Until 1892 the hatching of trout eggs was carried out in tanks in the cramped quarters of the Commissioners in Phillip street. After 1892 the operation was conducted at Prospect Reservoir on

1948 But the summer temperature of this water was over-looked and also the mineral content of the water itself. Thus disaster lay ahead for the C.A.Society once more.

Ten years of mixed success saw floods destroy ponds and warm waters kill hundreds of thousands of fry, also Hydra took a great toll of eggs, alvins and fry, as also algae in warm water.

1958 Fisheries Department talking of taking over all Hatcheries.

Burraga Hatchery to be taken over by State Fisheries - 31st December, 1960.

Administration of C.A.S. head Council in Sydney transferred to Bathurst, 1958 (Aug. 27th).

Fisheries to take over the Burraga Hatchery and do all the hatching and the C.A.S. to continue as a Society to work along with the State Fisheries in policing streams and liberating the fry and fingerlings as distributed by the Fishery.

1962 Some years were spent in trying to stock the rivers by using the Vibert Box method but was a failure. Our waters warm up all too quickly for this method.

1982 The Central Acclimatisation Society is still a registered body with the N.S.Wales State Fishery and has been operating for 45 years.

(1937-1982)

Ernest G. Green, Sec.
Western Branch, C.A.S.

3.3.82

THE EMBANKMENT

OR

PROSPECT DAM

Commemorative Plaque Nomination Form

Date: Oct - Nov 1993

To:
Commemorative Plaque Sub-Committee
The Institution of Engineers, Australia
11 National Circuit
BARTON ACT 2600

From: Engineering Heritage Committee, Sydney Division

(Nominating Division or Branch)

The following work is nominated for an *Historic Engineering Marker/[redacted] award:

Name of work: Prospect Dam

Location, including address and map grid reference if a fixed work: Prospect Reservoir, Sydney

Owner: Water Board, Sydney

In support of the nomination the following information is provided:

For an Historic Engineering Marker (HEM)

(1) Proposed wording on HEM# see a following page.

(2) Justification - please make data as complete as possible.# A pioneering example of earth and clay-core embankment, and largest in Australia in 1888.

~~For a National Engineering Landmark (NEL)~~

(1) Date of construction (or other significant dates).

(2) Names of key professional personnel associated with the work.#

(3) Historic engineering significance of the work.#

~~(4) Comparable or similar works (a) in Australia (b) overseas.#~~

(5) Features or characteristics setting the work above other engineering works.#

(6) Contribution towards the development of engineering and/or the nation.#

For all Nominations

The following documentation is attached in support of the nomination: (List all documents, photographs, etc, and enclose black and photographs). see following papers

The nomination has been discussed with the owner of the work who has indicated

Full support for plaquing and plans for long-term preservation
(Include statement regarding owner's attitude)

A copy of this submission has been sent to the Secretary of the NCEH

Division at ....
(For completion by a nominating body other than a Division)

In the event of this nomination being approved the nominating body will organise an suitable presentation/ unveiling ceremony.

[signature]
(Chairman of Nominating Committee

[signature]
(Secretary of Nominating Committee

* Delete as appropriate
# Where there is insufficient space, attach additional papers

WATER BOARD

Environment Management Unit,
15th Floor, 115-123 Bathurst St, SYDNEY NSW 2000
PO Box A53, SYDNEY SOUTH NSW 2000

8 November, 1993

Contact: Colin Heath
Tel: 350.5587

FOR COLLECTION a.m. 8/11/93

Mr. Don Fraser,
C/- Institution of Engineers,
NSW Division.

Dear Don

re: INSTITUTION OF ENGINEERS - PLAQUING OF PROSPECT RESERVOIR

Please find attached a copy of memorandum from Mr. Geoff Henstock, Executive Officer to the Appointed Board to Mr. Colin Heath regarding the abovementioned event.

Mr. Henstock has advised that the Managing Director has given approval for the Institution to recognise the Prospect Reservoir during Heritage Week in April 1994.

I will be Acting as Stormwater Manager, Central Region at our Rockdale office from Monday 8th November until at least 6th December, 1993 therefore could you deal directly with Geoff Henstock on telephone number 350.5148 if you have any queries regarding this event.

Yours sincerely

per: [signature]

Colin Heath
Principal Environmental Scientist

att.

For information: Reece McDougall

WATER BOARD
SYDNEY - ILLAWARRA - BLUE MOUNTAINS

COPY

Form 2-84 (Feb '93 A) Water Board Print

Reference ____________

9394pros.mem

MEMORANDUM

To: COLIN HEATH, EMU

From: EXECUTIVE OFFICER TO BOARD

Subject: **RECOGNITION OF ENGINEERING HERITAGE VALUE OF PROSPECT RESERVOIR - APRIL, 1994**

As you know, the attached letter of 21st September, 1993 to the Chairman from the Institution of Engineers proposes that a plaque be placed at Prospect Reservoir in recognition of its heritage value. It is proposed that this occur during Heritage Week in April, 1994.

The Managing Director has approved:

1) The Board's involvement in the Institution's plans to recognise Prospect Reservoir; and

2) Continued negotiations to borrow the Streeton painting of Prospect Reservoir. Negotiations are being pursued by the Regional Manager, Central (Mr Bill Hazell) and the Art Gallery of New South Wales.

It would be appropriate for your area to liaise with the Institution to organise the ceremony. Please advise me if it is decided to involve the Chairman and/or Board Members in the function.

G Henstock

Geoff Henstock
05.11.1993

c.c: Mr Bill Hazell

I E Aust
crest

HISTORIC ENGINEERING MARKER

PROSPECT DAM

WHEN COMPLETED IN 1888 THIS EARTH AND CLAY - CORE EMBANKEMENT WAS THE LARGEST IN AUSTRALIA AND WAS COMPARABLE WITH SIMILAR LARGE DAM PROJECTS OVERSEAS. IT WAS THE FIRST MAJOR COMPONENT OF THE UPPER NEPEAN SCHEME, AN ENGINEERING PLAN DEVISED AND INITIATED BY E. O. MORIARTY, ENGINEER-IN-CHIEF IN THE PUBLIC WORKS DEPARTMENT, TO ASSURE SYDNEY'S WATER SUPPLY WELL INTO THE 20TH CENTURY. THE RESERVOIR WAS THE PRINCIPAL WATER DISTRIBUTION POINT FOR OVER 100 YEARS.

DEDICATED BY
THE INSTITUTION OF ENGINEERS, AUSTRALIA
AND THE WATER BOARD 1994

THE EMBANKMENT

INTRODUCTION

The attachments to this nomination have a fair amount of repeated material but have all been included because they were written at different times by different authors for different reasons.

Chronologically, they range from contemporary reports at the time of construction through to the 1991 SMEC report on safety and stability.

Technically, they range from general engineering heritage interest to detailed comments by expert engineers in the fields of dams and soil mechanics.

Collectively, they form a complete historical overview and technical judgement of an engineering work that has served Sydney for over 100 years.

The following summary helps guide the reader through the attachments.

SUMMARY OF ATTACHMENTS

ATTACHMENT E1

The first item is a plan of Prospect Reservoir showing the embankment known as Prospect Dam. Not shown are the valve houses and the Lower Canal at the right hand end of the dam.

Of particular note are the kinks or "dog legs" in the dam alignment. The 1888 slips occurred in this region.

The second item is a cross-section drawing of the dam showing it to be a clay-core and earth fill structure. The upstream side is essentially original but there are plans to dump rock to create a large underwater stabilising berm. The downstream side was strengthened by two berms in 1980.

ATTACHMENT E2

This extract from the ANCOLD Register on large dams in Australia shows that at the time of its construction, Prospect Dam was neither the first nor the heighest earth and clay-core dam in Australia, but, it was way and above the largest. Columns 9, 10 and 11 show that its length, its volume and the capacity of the reservoir were significantly larger than its predecessors and contemporaries.

It was well into the 20th century before improvements in the theory and practices of soil mechanics enabled larger projects of this type to be designed and built.

Professor R. Fell, Department of Geomechanics, University of New South Wales, who specialises in this technology and is a member of the Water Board's review team, is of the opinion that the design engineers and builders were on the "cutting edge" of soil mechanics which was not formalised until 40 years later by Terzaghi.

ATTACHMENT E3

Construction of the embankment began in the early 1880's and was completed in early 1888. In 1886 the eminent british civil engineer Sir John Fowler, of Firth of Forth Bridge fame, visited Sydney and the NSW Government asked him to inspect and report on progress at Prospect.

Copies of the handwritten request and reply are attached, 16 pages in the case of Sir John. Page 14 contains high praise indeed, from one so widely acknowledged on the world engineering stage, for the work of his colonial engineering colleagues.

His postscript indicates that Prospect Dam compared favourably with similar large projects in England and India.

A biography of Sir John Fowler is the last item of this attachment.

The Water Board Archives have the diaries of the Resident Engineer in which he has recorded the names of all the VIP visitors, many of whom were overseas engineers, indicating that the project had attaracted international attention.

ATTACHMENT E4

Despite Sir John Fowler's assurance "that no anxiety need be sustained of their sufficiency and safety", two large slips on the upstream face in the region of the "dog legs" (3 drawings attached) did cause local anxiety, so much so that a Royal Commission was formed to review the work and reassess the safety of the dam.

Many prominent colonial engineers, incuding F. A. Bishop (a leading civil engineer), John Whitton (Chief Engineer for the Railways), W. C. Bennett (Chief Engineer for Roads and Bridges) and Robert Hickson (Under Secretary for Public Works and later Head of the Sydney Harbour Trust), inspected the work and the slips and submitted reports (attached).

They all reported favourably on the quality of the construction and gave assurances as to safety.

The subsequent 100-year performance of the embankment vindicted their judgements.

A summary of the Commission's findings conclude this attachment.

ATTACHMENT E5

The 1991 SMEC report is the most comprehensive review of Prospect Dam available. Its value for engineering heritage lies in the ability of today's experts to judge the quality and performance of the dam, in retrospect.

The attached extracts from the SMEC report contain a great deal of technical matters best suited to expert engineers for whom it was written, but from it, the following points emerge,

1. While the reservoir was being filled for the first time in April 188 a major slip occurred between the "dog legs". Then in Novemebr during rapid drawdown another slip occurred in the same area.

2. Rockfill proved to be an effective remedy.

3. The puddled core trench was a major feat.

4. There was progressive settlement over the next 15 years and other remedial works were carried out, but none in response to a threat to safety.

5. By 1902 operators of the reservoir realised that slow drawdown avoided slips along the upstream face. No slips have occured since 1903.

6. The performance of the clay-core material over the years indicates that it was well suited to the job it had to do.

7. It is doubtful that the standard of compaction of the main fill would be acceptable by modern day practices.

8. The downstream face was stabilised in the late 1970's by the addition of two earth berms.

9. The dam is not in a state of failure. However, due to the Sydney urban sprawl, the areas downstream of the dam are now heavily populated. This has raised the classification of the dam to that of "a high hazard dam" or "prescribed".

10. A new criteria for earthquake safety has been set as the 1 in 10,000 year event. In order to achieve the desired factor of safety, the Water Board will be forming a new underwater berm on the upstream side (see newpaper clippings at end of SMEC extracts).

From the above, there is a clear inference that, despite the faults revealed by modern soil mechanics technology, the Prospect Dam was a major achievement for its day and that today's concern about safety is due mainly to changed social factors (the risk to new residential areas downstream) rather than the lack of sound engineering practice on the part of the colonial engineers.

ATTACHMENT E6

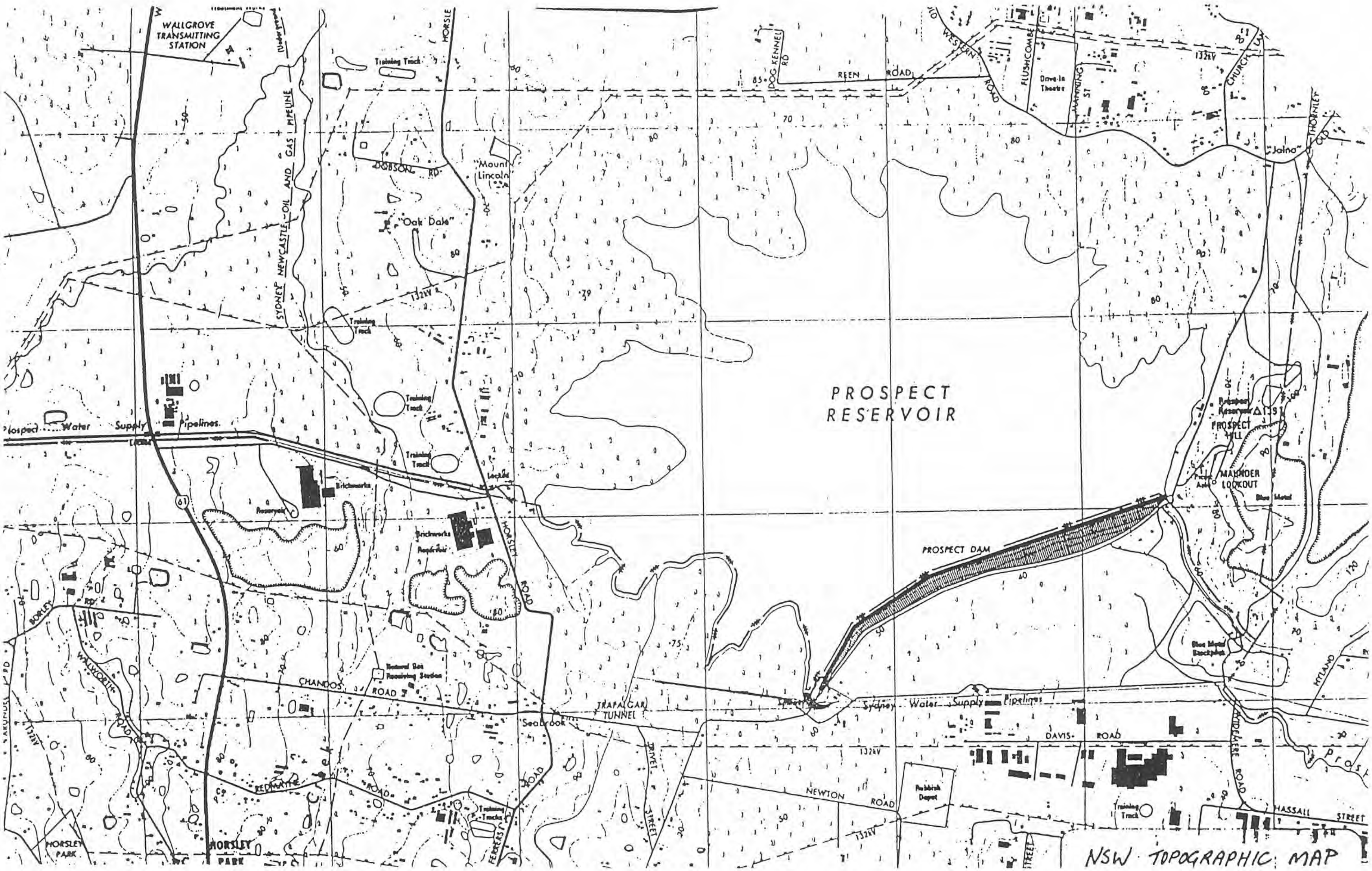
The National Trust of Australia (NSW Branch) has classified Prospect Dam and Trust's documentation forms this attachment. The dam is not part of the National Estate but if it is awarded an Historic Engineering Marker, steps will be taken to nominate it for inclusion in the Register of the National Estate.

ATTACHMENT E7

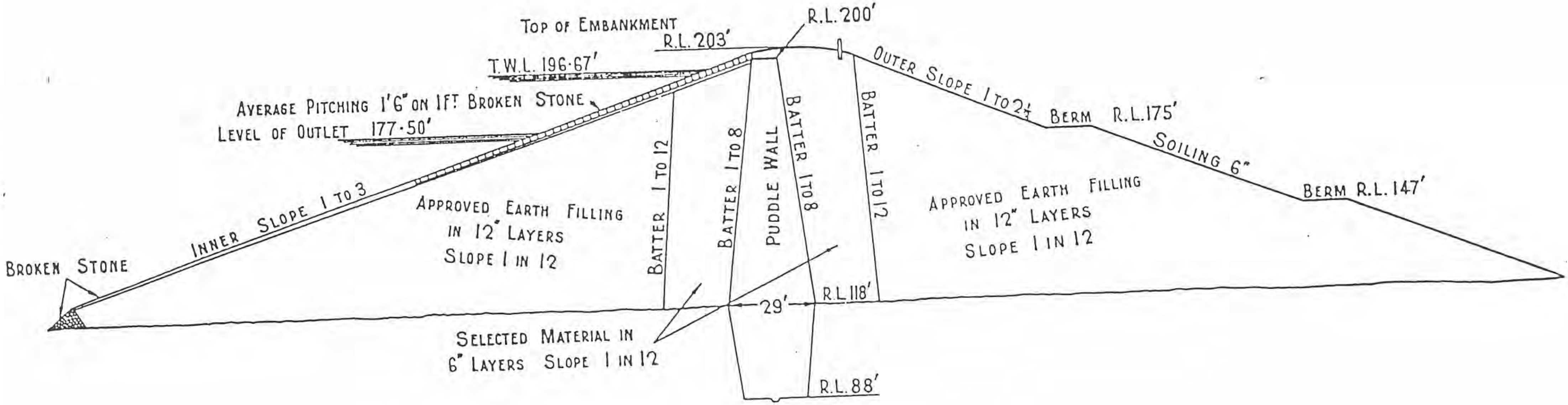
Apart from the embankment itself, the only relics from the construction work of the 1880's is the stone pad-foot roller used to compact the layers of clay-core and earth fill.

The attached papers and the 1993 photographs are self-explanatory.

E1



NSW TOPOGRAPHIC MAP



PROSPECT DAM

Typical Cross Section

Crest Length. 7321 Ft – Max. Height 85 Ft – Max. Width at Base 514 Ft

E2

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
LIGNE *LINE* No	NOM DU BARRAGE *NAME OF DAM*	ANNÉE D'ACHÈVEMENT *YEAR OF COMPLETION*	SITUATION · *LOCATION* COURS D'EAU *RIVER*	VILLE LA PLUS PROCHE *NEAREST CITY*	ETAT PROVINCE OU DÉPARTEMENT *STATE PROVINCE OR COUNTY*	TYPE	HAUTEUR AU-DESSUS DE LA PLUS BASSE FONDATION *HEIGHT ABOVE LOWEST FOUNDATION* (m)	LONGUEUR DE CRÊTE *LENGTH OF CREST* (m)	VOLUME DU BARRAGE *VOLUME CONTENT OF DAM* (10^3 m³)	CAPACITÉ TOTALE DU RÉSERVOIR *GROSS CAPACITY OF RESERVOIR* (10^3 m³)	DESTINATION *PURPOSE*	CAPACITÉ MAXIMALE DES ÉVACUATEURS *MAXIMUM DISCHARGE CAPACITY OF SPILLWAYS* (m³/s)	TYPE DES ÉVACUATEURS *TYPE OF SPILLWAYS*	PROPRIÉTAIRE *OWNER*	BUREAU D'ÉTUDES *ENGINEERING BY*	CONSTRUCTEUR *CONSTRUCTION BY*	LIGNE *LINE* No
1	YAN YEAN	1857	OFF RIVER STORAGE	MELBOURNE	VICTORIA	TE	12	986	206	32 710	S	10	L	MELBOURNE & METROPOLITAN BOARD OF WORKS	WATER SUPPLY DEPARTMENT	MARTINDALE & STEELE	1
2	LOWER RESERVOIR	1861 *	SANDY BAY RIVULET	HOBART	TASMANIA	TE	18	104		210	S			HOBART CITY COUNCIL			2
3	ENOGGERA	1866	ENOGGERA	BRISBANE	QUEENSLAND	TE	24	342	95	4 500	S	450	L	BRISBANE CITY COUNCIL	JOSEPH BRADY & BRISBANE BOARD OF WATERWORKS	DONOVAN & HULSE	3
4	UPPER STONY CREEK NO. 1	1868	STONY CREEK	GEELONG	VICTORIA	TE	29	404		3 420	S	40	L	GEELONG WATERWORKS & SEWERAGE TRUST	VICTORIAN WATER SUPPLY DEPARTMENT	JONOTHAN CHAPPELL	4
5	SPRING GULLY	1868 *	SPRING CREEK	BENDIGO	VICTORIA	TE	24	512		2 500	S	4	L	STATE RIVERS & WATER SUPPLY COMMISSION, VICTORIA			5
6	BARKER'S CREEK	1869	BARKER'S CREEK	CASTLEMAINE	VICTORIA	TE	13	684		2 700	S	4	L	STATE RIVERS & WATER SUPPLY COMMISSION, VICTORIA			6
7	MALMSBURY	1870 *	COLIBAN	KYNETON	VICTORIA	TE	24	662		18 000	S	736	V	STATE RIVERS & WATER SUPPLY COMMISSION, VICTORIA	S.R.& W.S. COMMISSION, VICTORIA (FOR ENLARGEMENT)	S.R.& W.S. COMMISSION, VICTORIA (FOR ENLARGEMENT)	7
8	NEWLYN	1871 *	BULLAROOK CREEK	DAYLESFORD	VICTORIA	TE	12	741		3 300	S	255	L	STATE RIVERS & WATER SUPPLY COMMISSION, VICTORIA	STATE RIVERS & WATER SUPPLY COMMISSION, VICTORIA	STATE RIVERS & WATER SUPPLY COMMISSION, VICTORIA	8
9	HOPE VALLEY	1872	TORRENS	ADELAIDE	STH. AUST.	TE	22	765	236	3 440	S	12	L	STH.AUST.GOVERNMENT ENG. & WATER SUPPLY DEPARTMENT	STH.AUST.GOVERNMENT ENG. & WATER SUPPLY DEPARTMENT	G.& R.E. FRY & STH.AUST.GOVT. ENG. & WATER SUPPLY DEPARTMENT	9
10	CRUSOE	1873	-	BENDIGO	VICTORIA	TE	12	624		1 500	S	4	L	STATE RIVERS & WATER SUPPLY COMMISSION, VICTORIA			10
11	LOWER STONY CREEK	1875	STONY CREEK	GEELONG	VICTORIA	PG	21	69	4	640	S	45	L	GEELONG WATERWORKS & SEWERAGE TRUST	VICTORIAN WATER SUPPLY DEPARTMENT		11
12	GONG GONG	1877	FELLMONGERS CREEK	BALLARAT	VICTORIA	TE	30	278		1 830	S	8	L	BALLARAT WATER COMMISSION			12
13	GOLD CREEK	1885	GOLD	BRISBANE	QUEENSLAND	TE	26	191	106	990	S	-	L	BRISBANE CITY COUNCIL	J.B.HENDERSON & BRISBANE BOARD OF WATERWORKS	ROSS & DUNBAR	13
14	EVANSFORD	1887 *	McCALLUMS CREEK	MARYBOROUGH	VICTORIA	PG	17	76		1 620	S	227	L	MARYBOROUGH WATERWORKS TRUST			14
15	WARTOOK	1887	McKENZIE	STAWELL	VICTORIA	TE	11	1 416		29 500	S	566	L	STATE RIVERS & WATER SUPPLY COMMISSION, VICTORIA			15
16	UPPER RESERVOIR	1888 *	SANDY BAY RIVULET	HOBART	TASMANIA	TE	18	204		290	S			HOBART CITY COUNCIL			16
17	PROSPECT	1888 *	PROSPECT CREEK	SYDNEY	N.S.W.	TE	26 *	2 225	1 913	50 200	S	14 +	L	METROPOLITAN WATER SEWERAGE & DRAINAGE BOARD, SYDNEY	DEPARTMENT OF PUBLIC WORKS, N.S.W.	DEPARTMENT OF PUBLIC WORKS, N.S.W.	17
18	MT. COLE	1889 *	MT. COLE	ARARAT	VICTORIA	VA	24	112		400	S	–	L	ARARAT CITY WATER SUPPLY COMMISSION	B.A. & D.B. SMITH		18
19	GOULBURN WEIR (NAGAMBIE RES.)	1890	GOULBURN	NAGAMBIE	VICTORIA	PG	15	212	14	25 000	I	1 897	V	STATE RIVERS & WATER SUPPLY COMMISSION, VICTORIA	VICTORIAN WATER SUPPLY DEPARTMENT	VICTORIAN WATER SUPPLY DEPARTMENT	19
20	BEETALOO	1890	CRYSTAL BROOK CREEK	PT. PIRIE	STH. AUST.	PG	37	179	44	3 680	S	80	L	STH.AUST.GOVERNMENT ENG. & WATER SUPPLY DEPARTMENT	STH.AUST.GOVERNMENT ENG. & WATER SUPPLY DEPARTMENT		20
21	LAANECOORIE	1891	LODDON	MARYBOROUGH	VICTORIA	TE	22	399		8 000	I	71	V	STATE RIVERS & WATER SUPPLY COMMISSION, VICTORIA			21
22	VICTORIA RESERVOIR	1891	MUNDAY'S BROOK	PERTH	WEST. AUST.	PG	22	222		850	S	150	L	METROPOLITAN WATER SUPPLY SEWERAGE & DRAINAGE BOARD, PERTH			22
23	MANLY	1892 *	CURL CURL CREEK	SYDNEY	N.S.W.	PG	20 *	256	8	2 000	C	178	L	METROPOLITAN WATER SEWERAGE & DRAINAGE BOARD, SYDNEY	DEPARTMENT OF PUBLIC WORKS, N.S.W.	DEPARTMENT OF PUBLIC WORKS, N.S.W.	23
24	STEPHENS CREEK	1892 *	STEPHENS CREEK	BROKEN HILL	N.S.W.	TE	18 (17)	256	72	24 325 + (17 885)	S	91	L	BROKEN HILL WATER BOARD	BROKEN HILL WATER SUPPLY CO.	BROKEN HILL WATER SUPPLY CO.	24
25	BETHUNGRA	1895	WANDALY-BENGLE CREEK	BETHUNGRA	N.S.W.	PG		161		580	S	120	L	NORTHERN RIVERINA COUNTY COUNCIL	DEPARTMENT OF PUBLIC WORKS, N.S.W.		25

NOTES
FOOTNOTES

(2) AS REQUIRED FOR WATER SUPPLY
(5) RAISED 1929
(7) RAISED 1887. GATES ADDED 1940
(8) RAISED 1961
(14) RAISED 1940
(16) AS REQUIRED FOR WATER SUPPLY
(18) RAISED 1926
(23) RAISED 0.5M in 1909, 0.5M IN 1914 AND 6M IN 1922
(24) RAISED 1909 - BRACKETED FIGURES REFER TO ORIGINAL STRUCTURE
\+ DUE TO SILTATION, 20 554 IN 1969

INTERNATIONAL COMMISSION ON LARGE DAMS

AUSTRALIAN NATIONAL COMMITTEE

REGISTER OF LARGE DAMS IN AUSTRALIA

TABLE OF CONTENTS

December 1976

GLOSSARY OF DEFINITIONS, TERMS AND ABBREVIATIONS

1. Definition of Large Dam

A Large Dam is defined as one which is -

(a) more than 15 metres in height measured from the lowest point of the general foundations to the "crest" of the dam,

(b) between 10 metres and 15 metres in height, measured as in (a), provided they comply with at least one of the following conditions:

(i) the crest length is not less than 500 metres.

(ii) the capacity of the reservoir formed by the dam is not less than 1 million cubic metres.

(iii) the maximum flood discharge dealt with by the dam is not less than 2,000 cubic metres per second.

(iv) the dam has specially difficult foundation conditions.

(v) the dam is of unusual design.

No dam less than 10 metres in height may be included.

2. Year of Completion (Column 3 in Register)

The year shown is that during which the dam was originally completed unless advised otherwise by the owner. Where subsequent raising of the dam has been carried out this is indicated in the footnotes. The symbol C indicates "Under Construction" and the figure below indicates the expected completion date. Symbol P indicates "Proposed".

3. Type of Dam (Column 7 of Register)

TE - Earth

ER - Rockfill

PG - Gravity

CB - Buttress

VA - Arch

MV - Multiple Arch

The symbol VA includes such variations of arch dams as constant radius, cupola and all other forms.

The symbol MV includes multiple domes.

4. Height of Dam (Column 8 of Register)

The "Crest" of the dam is defined as the level of the roadway or walkway on the dam or alternatively the maximum water level plus the designed freeboard. For weirs and dams with spillways only the "Crest" level is taken as the level at which water overflows the spillway. The height above lowest foundation level refers to the vertical distance between "Crest" level and the level of the lowest portion of the general foundation.

5. Length of Crest (Column 9 of Register)

This includes the spillway crest length in those cases where the spillway is within the limits of the dam proper or continuous with the dam crest.

6. Volume Content (Column 10 of Register)

Total quantities only are shown. Where significant divisions occur they are indicated in the footnotes. Symbols used for these are:

Concrete (A)
Rockfill (B)
Earthfill (C)

7. Purpose (Column 12 of Register)

I - Irrigation
H - Hydro-electric development
C - Flood control
N - Navigation
S - Water supply
R - Recreational purposes

Other uses are explained in footnotes.

8. Spillway Capacity and Type (Columns 13 and 14 in the Register)

Symbols used for the type of spillway are:

L - Uncontrolled Spillway
V - Controlled Spillway.

E3

Department of Public Works 86/3186 205

[signature] 16.3.86

Railways and Roads Branch,
Sydney March 16th 1886.

Minute Paper.

Subject: Suggesting that Sir John Fowler be requested to examine and report on Prospect Reservoir.

The Engineer in Chief for Harbours & Rivers
to
The Under Secretary for Public Works.

Referring to my verbal recommendation to Mr Secretary Lyne that advantage should be taken of the presence of Sir John Fowler in the Colony to obtain from him a report on the Prospect Dam, I have now the honour to repeat the request officially.—

As the Minister is aware, the Prospect Dam is a work of unusual magnitude, requiring the greatest care and skill in every detail of its design and construction.— Although I feel confident that everything is being done to ensure its safety, and thorough success, yet I think – that having regard as I have stated, to its

Report On Prospect Dam. 1886.

unusual magnitude, and the greatness of the interest involved in its safe and economical construction, – it would be a matter of the greatest satisfaction to me, as I have no doubt it would also be to the Government, to have the approval of a gentleman of Sir John Fowler's great experience in water works, if he should find himself able to approve of the manner in which the work is being constructed, or of any suggestion for its improvement he should find it advisable or necessary to make. –

As regards Sir John Fowler's charge, I presume it would be left to him after examining into the matter, to say what his fee would be.

WMurray

[Marginal note:] Send for other letters and copies of [illegible] and documents [illegible] copies of Sir John [illegible] letters [illegible]

Report On Prospect Dam. 1886.

Sir John Fowler.

Report on the Works of the Prospect Dam Sydney Water Supply

Sydney

23rd March 1886

To the Honorable W. J. Lyne

Minister for Works

Submitted 9/4/86

Sir/

I have the honor to acknowledge your request that I should examine the Works of the Prospect Dam, now in course of construction.

The object of my examination, as you explained to me personally; was solely with reference to the

Stability

Put with other papers

of the dam, and the Works immediately connected therewith, and not with reference to the merit of the whole scheme as a Water Supply to Sydney, either as regards itself, or in comparison with any other scheme.

Under these circumstances I do not consider it necessary to make you a detailed report on the subject.

Before proceeding to the site of the dam I thought it proper to examine, at Mr Moriarty's office, not only the detailed drawings of the dam itself, but also

also those of the works for admitting the water into the dam, and those for drawing off the water by the water course to Sydney, by the Waste Weir, and by the pipes for emptying the reservoir, all works of the highest importance, and intimately connected with the efficiency and safety of the dam.

I also checked the various hydraulic calculations, and made my own, so far as appeared to me to be necessary for the objects of my report; and I also availed myself of the valuable information on rainfall obtained by Mr Russell, the

the Government Astronomer.

I was anxious to investigate these questions from the fact, which is well known to you, and to every one in the Colony, that the periods of rainfall and drought, and the quantity of rain at various times, are more irregular than in England, and therefore the provisions for adequate storage, overflows, &c must be far greater.

The important duty of examining the character and quality of the work on the spot was my next step.

Fortunately the present condition

of

of the Works is peculiarly favorable for this practical examination, as every part and description of work is in progress, and open to view. I was accompanied over the Works by Mr. Moriarty, Mr. Darley, and Mr Ryan, the Resident Engineer; and also by the Contractor and his resident manager.

The quantity of material already placed in the dam is something more than one third of the whole, and, at the present rate of progress, about three years will be required for its perfect completion.

I

With respect to the Prospect Dam it gives me great pleasure to be able to report that the dam itself, and the masonry, tunnels, and works connected therewith, are of a character worthy of their importance, and creditable to all persons connected with them, and that no anxiety need be entertained of their sufficiency and safety.

I have the honor to be,

Sir,

Your obedient servant

[signature]

14.

Postscript

It may be interesting to record, in connection with this report on the Prospect Dam, that the puddle trenches of several well known and successful dams have been taken to a far greater depth into the ground than is being done in the case of the Prospect dam. For instance - for the Yarrow reservoir near Liverpool the puddle trench was taken 97 feet into the solid, as compared with 50 feet at the Prospect; and many other dams are of greater or equal height; viz:- The Yarrow reservoir, with

with 100 feet above the natural surface – the Grenwith at Bradford with 87 feet, – the Barden at Bradford 80 feet – the Silsden at Bradford 88 feet, whilst the Prospect dam is 83 feet.

There are many others of at least Equal height in different parts of the World, and in India several are of greater magnitude as regards cubical Contents.

[signature]

Sir John Fowler, K.C.M.G.

The period over which Sir John Fowler's career extends practically coincides with that of the profession of modern engineering. In saying this we do not forget the illustrious men who preceded him, such as Telford, Trevithick, Watt, Smeaton, and Rennie. But these all flourished before the manufacture of iron, and the tools for working it, had so far progressed that it was readily available for every-day use. Many of them executed splendid works in brick and stone, works which will uphold their reputations for centuries, and others of them were capital mechanics. But it was not then practicable to use iron, and particularly wrought iron, for large structural purposes. It is worth while to recall a few instances in exemplification of this fact which is often forgotten. The first flour mill which had iron wheels and shafting was erected by Rennie in 1788. The first iron bridge was designed by French-Italian engineers in 1755, and was attempted to be constructed at Lyons, but the founders proved unable to cast it. In 1777 a cast-iron bridge of 100 ft. span was erected at Coalbrookdale, and this was followed in 1796 by one over the Wear. This latter had been constructed to the directions of the celebrated Tom Paine for a different site. A third bridge was erected by Telford over the Severn about the same date, and he constructed four other cast-iron bridges before the century terminated. Rennie's first iron bridge was opened in 1803 at Boston. It is thus shown that the employment of iron on a large scale during the eighteenth century was practically unknown. In the early part of the nineteenth century, cast-iron was largely used for bridges, for canal aqueducts, for locks, and for dozens of other purposes, only to be supplanted in its turn by wrought iron. When this metal could be obtained cheaply and abundantly, engineering science entered upon a new phase of its existence, and the world commenced to progress at a speed hitherto undreamed of.

It was under conditions such as these that the subject of our sketch entered his professional career. He was born in 1817 at Wadsley Hall, Sheffield, the residence of his father, Mr. John Fowler, and when his general education was completed, the boy, at the age of seventeen, became a pupil of Mr.

From a photograph by the London Stereoscopic Company.

Yours very truly

John Fowler

Here he had ample facilities for obtaining a thorough training in several branches of his calling, and in all cases his experience was gained in works of very considerable magnitude. Yorkshire enjoys the advantage of possessing a great number of diverse industries, and it was very early in the field as a manufacturing district. From its coal, iron, steel, and woollen trades, in addition to its farming and shipping pursuits, great wealth was rapidly accumulated after the close of the bad times following the Napoleonic wars. The entire world was then the customer of England, and the shrewd people of the Ridings managed to secure a large share of the trade. The county thus was able to find employment for many engineers, and among them Mr. Leather took a leading position. He executed many works for the supply of water, notably those of Sheffield. The Stockton and Darlington line was opened when Mr. Fowler was only eight years of age, and the Liverpool and Manchester Railway when he was but thirteen. He had not completed his pupilage before the rush, which eventuated in the railway mania, commenced.

When Mr. Fowler left Mr. Leather he went straight into the railway world, finding in the office of Mr. J. U. Rastrick a very wide field. He became his chief assistant in the preparation of the drawings and contracts for several railways; among these was the line from London to Brighton. To this latter Mr. Fowler gave great attention, and there is scarcely a bridge or viaduct which was not personally worked out by him. After two years spent in London, he returned to Mr. Leather, and became responsible resident engineer of the Stockton and Hartlepool Railway. After it was completed he remained two years as engineer, general manager, and locomotive superintendent of that and the Clarence Railway. It is no wonder that these engineers of the old school can turn from one subject to another with so much versatility when we consider what an education they had. Instead of having professors to fill them with ready digested knowledge, like the young men of the present day, they were moved from one position of responsibility to another, and their intellects were hardened and invigorated by constant work. Every step they took was an experiment on a working scale, and every fact they learned was imprinted on their memories by the toil and trouble it had cost.

On the termination of this engagement, Mr. Fowler visited, at the invitation of Sir John Macneil, several railways in the neighbourhood of Glasgow, and gave evidence before Parliamentary committees regarding them. He commenced an independent career at the age of twenty-six, and as we have already seen, he started with a broad and solid foundation of experience, suitable for the towering reputation which was to be built upon it. Several important railways were then being promoted from Sheffield, such as the Sheffield and Lincolnshire, the Great Grimsby, the New Holland, the East Lincolnshire, and others, and of these Mr. Fowler became the chief engineer, conducting them through Parliament and carrying them out. It was in the year 1843 that this work was commenced, and before it was completed the railway mania attained its full proportions. The history of that movement has often been written; how fortunes were made and ruined in a day; how men lost their reason in a moment both from good and evil tidings, and how the capital subscribed during those years, often for the wildest undertakings, almost rivalled the days of the South Sea Bubble. We have no intention of redrawing the picture, but the following incident will show at what high pressure engineers were expected to work in those days. One night when Mr. Fowler was asleep in his father's house, a carriage and four drove up to the door, and the household was aroused by loud knocking. On descending Mr. Fowler found that a prominent promoter of railways had called with the purpose of inducing him to undertake the engineering of a new railway from Leeds to Glasgow, and that as an earnest he had brought an order for 20,000*l*., as a preliminary payment on account of the survey expenses. It then only wanted a very few weeks (quite inadequate for the purpose) before the day of depositing the plans. Mr. Fowler had the prudence to decline the offer, and the carriage of the disappointed promoter went thundering away, the occupant little dreaming how many years would elapse before his plan would be carried out.

It was only men of iron constitution that came unscathed through those times, and many an engineer able to husband his strength, threw away his life in furthering the schemes of the promoters. When the autumn approached, and the fatal thirtieth of November hove in sight, surveys and drawings had to be made at the greatest possible speed. The hours of the night were annexed—sometimes all of them—to supplement those of the day, while meals had to be taken when they could, or not at all. The deposit of the plans brought rest to the rank and file, but the chief responsible engineer had then to enter upon the still more trying work of preparing for, and attending, Parliamentary committees. Often he had to appear before three or more committees in one day, pitting his wits against those of half a dozen counsel, backed by eminent opposing engineers. The engineer could not imitate the members of the bar, and choose in what cases he would appear and which he would neglect, taking his fees for all. Indeed, it is said that Charles Austin, the leader of the bar in the committees of the House of Commons, had once been engaged to appear before twenty-two committees in one day, and as it was impossible for him to attend to them all, he showed his impartiality by reading his newspaper and attending to none. The progress of committee work was watched with keenest interest by men who did not know an embankment from a cutting, but who took advantage of every turn of the fight to manipulate the share market. They listened to the evidence of the engineer and sold and bought accordingly. If he tripped in his advocacy of a measure, or was foiled in his attack on a hostile scheme, they hurried to anticipate the effect on the money market. Mr. Fowler once met an acquaintance rushing along the corridor of the House in the wildest excitement, and when he stopped him to learn the cause, the man exclaimed, "Don't detain me! Robert Stephenson has broken down in his attack, and I am off to buy a thousand Great Northerns." Everybody gambled in shares, and like all gamblers their choice was determined by the merest trifles. If a line were fortunate, promoters would endeavour to appropriate as much of its name as they could for other lines, in the hope that their particular venture would gain by the association. As an instance Mr. Fowler's Great Grimsby Railway was at a premium, and consequently the name of Great Grimsby was brought in quite irrespective of geographical facts. This was done to such an extent that the then chairman of committee (Lord Devon) exclaimed "What! Great Grimsby again! Go it, Great Grimsby!"

Mr. Fowler had now attained a position which necessitated his permanent residence in the metropolis, and work of all kinds flowed in to him. It is quite beyond the limits of our space to notice, much less to describe, one-half of the matters about which he was consulted or the works he carried out. Amongst them we may mention the following: The Oxford, Worcester, and the Wolverhampton Railways; the Severn Valley Railway; the London, Tilbury, and Southend Railway (in conjunction with Mr. Bidder); the Liverpool Central Station, the Northern and Western Railway of Ireland, the railways of New South Wales and India, the Sheffield and Glasgow Water Works, the Metropolitan Inner Circle Railway, the St. John's Wood Railway, the Hammersmith Railway, the Highgate and Midland Railway, the Victoria Bridge and Pimlico Railway, the Glasgow Union and City Railway, and St. Enoch's Station, the Millwall Docks, the Channel Ferry, and many others.

Mr. Fowler's reputation with the general public of this generation rests to a great degree on his construction of the Metropolitan Railways. These were so far out of the common that every Londoner, and a great many people out of London, took the greatest interest in them. The most extravagant anticipations were indulged in as to the relief they would afford to the streets if they were ever completed. But the difficulties were so enormous that many, if not most, people imagined that they could not be overcome. The directors were constantly being told that they had embarked their own money and that of the shareholders in an impossible enterprise. Engineers of eminence assured them that they could never make the railway, that if they made it they could not work it, and if they worked it nobody would travel by it. Such a catalogue of impossibilities was enough to appal any man, and often faith in the enterprise fell to a low ebb. At such times they would say to Mr. Fowler, "We depend upon you, and as long as you tell us you have confidence we shall go on." man who had already sufficient to attend to in combating the physical difficulties of the affair. The troubles with vestries and their engineers and officials, with owners of property and their agents, were for many years during the construction of the first section of the Metropolitan Railway tedious and wearying to the last degree. All these were finally overcome, and the line was opened. So far from there being a difficulty in inducing people to travel by it, the traffic astonished the most experienced railway experts. The general public did not take the view laughingly expressed by Lord Palmerston when asked by Mr. Fowler to perform the opening ceremony, "I intend to keep above ground as long as I can." Of course they grumbled at the ventilation, or rather the want of it, and reproached the engineers for not improving it. Originally, when a junction with other railways was not intended, a special hot-water engine without a live fire, and therefore not passing the products of combustion into the air of the tunnel, was proposed. Experiments were made with an engine so constructed, but before it was perfected it was decided to make a junction with the Great Western Railway, and, therefore, locomotives of ordinary construction had to be admitted on the system.

It was in 1853 that the first Act was obtained for a line $2\frac{1}{2}$ miles in length from Edgware-road to Battle Bridge, King's Cross. Plans for extensions westward to Paddington, and eastward to the City, were at once prepared, and the financial support of the Great Western Railway was secured. After a severe fight, the Act for the extended railway was obtained, the plans providing for tunnels and stations large enough to accommodate the broad gauge Great Western trains, as well as the narrow gauge local trains which it was designed to run. There was, however, a difficulty in raising the capital, and it was not till the spring of 1860 that the contract was made, and the works commenced. In 1861 powers were obtained for extending the Metropolitan Railway to Moorgate-street; and in 1864, for constructing the eastern and western extensions to Tower Hill and Brompton respectively. In 1863 a Lords' Committee decided that it would be desirable to complete an inner circuit of railway that should abut upon, if it did not actually join, nearly all the principal termini in the metropolis, commencing with the extension in an easterly and southerly direction of the Metropolitan Railway, from Finsbury Circus at the one end, and in a westerly and southerly direction from Paddington at the other, and connecting the extremities of those lines by a line on the north side of the Thames. The inner circle was the direct outcome of this recommendation.

The construction of the so-called Underground Railway was the means of solving a great many problems which at the time presented much difficulty. Questions which are now fully understood, and which would be undertaken by contractors as a mere matter of course, then were of very grave importance, and had not only to be exhaustively discussed, but to be attacked with the greatest caution. It was not then known what precautions were necessary to insure the safety of valuable buildings near to the excavations; how to timber cuttings securely and keep them clear of water without drawing the sand from under the foundations of adjoining houses; how to undermine walls, and, if necessary, to carry the railway under houses and within a few inches of the kitchen floors without pulling anything down; how to drive tunnels; to divert sewers over and under the railway, to keep up the numerous gas and water mains, and to maintain the road traffic when the railway was being carried on underneath; and finally, how to construct the covered way so that buildings of any height and weight might be erected over the railway without risk of subsequent injury from settlement or vibration. All these points Mr. Benjamin Baker declared, in a paper read some five years ago before the Institution of Civil Engineers, received much anxious discussion and criticism before they were decided upon. Such questions as the admissible stress on brick arches loaded on one haunch only, the extent to which expansion and contraction of iron girders would affect buildings carried by them, the ability of made ground to resist the lateral thrust of arches, and a multitude of similar problems, had to be dealt with tentatively at first, and with increased boldness as experience was gained. As an instance of the confidence which experience gives we may cite the following: doubts

entertained by the engineers as to the behaviour of a compound brick and iron structure led to a timber front being put to the Edgware-road Station, where it rested on a 49-ft. span girder; yet in 1865, when the extension to Moorgate was executed, no hesitation was felt in trusting an elaborate brick and ashlar face wall, weighing 1300 tons, to a continuous girder 135 ft. in length.

It would be tedious and unprofitable to attempt to give a detailed account of the construction of the Inner Circle line, since the lessons taught by it have long ago been incorporated into the routine of engineering practice. It will ever remain a monument to the skill of the engineers concerned in its construction. Of these Mr. Fowler is responsible for the greater part, as shown by the annexed Table, which gives the lengths and percentages due to each.

Inner Circle Railway.

	Length Executed. miles	ch.	Percentages.
Mr. John Fowler, engineer	11	20	86
Mr. Edward Wilson, ,,	0	27	2½
Mr. Francis Brady, ,,	0	28	2½
Mr. Joseph Tomlinson, Jun.	0	35	3½
Messrs. Hawkshaw and Barry	0	58	5½
	13	8	100

The main lines of the Metropolitan and Metropolitan District Railways being complete, Mr. Fowler carried out the lines in connection with them, including the St. John's Wood Railway, the Hammersmith line, the West Brompton line, and others. His original plan, brought before the Parliamentary Committee, included an outer circle as well as an inner circle. Unfortunately, the Committee was induced to reject the outer circle on the faith of certain promises made by another line. These promises have not been practically fulfilled, and the immense advantage of being able to conduct all through passenger, goods and mineral traffic by a perfect and comprehensive scheme around London was lost for ever.

Although somewhat out of chronological order, we may here refer to another underground railway, of which Mr. J. H. Greathead is the engineer. This railway—the City and Southwark Subway—is not opened at the time of writing, but it is rapidly approaching completion, and great hopes are entertained that it will be the pioneer of a new system of railways which will prove as great a convenience as those already in existence in the metropolis. The ventilation difficulty is avoided entirely by the device of using electric power for the propulsion of trains, while the expensive work of diverting sewers and pipes, underpinning buildings, disappropriating tenants, and buying property, is evaded by keeping the tunnels at a very low level. As the line follows, for the most part, the streets, there is little to pay for land, and the chief expense is that of construction. A Bill now before Parliament contemplates the creation of a second railway of this kind from Bayswater to King William-street, E.C., Sir John Fowler, Mr. B. Baker, and Mr. J. H. Greathead being the engineers. If it is made it will prove the greatest advantage to Londoners.

Mr. Fowler was elected President of the Institution of Civil Engineers for the year 1866, and took the chair for the first time in that capacity on January 9. His presidential address was devoted to the subject of the education of an engineer, and was so important and valuable that it has been reprinted and distributed extensively, notably by the Government of India to the engineers in its employment. He began by calling attention to the fact that the exclusive position hitherto held by the English engineers was not likely to continue, since both in France and Germany great efforts were being made to educate young men both theoretically and practically for this profession. Hence, although this was greatly to the advantage of engineering science, it behoved the Institution to see that the distinguished and leading position which had been so well maintained by their great predecessors, should not be lowered by those who came after them. After a short enumeration of the nature of the works and duties which fell to the lot of a civil engineer, he proceeded to enforce the necessity of a full comprehension of the nature and qualites of materials, and the proper adaptation of the design to the materials in which it was to be carried out. He asserted his conviction that it was most important that the early preparation and subsequent study of an engineer should be as extensive as possible, and should embrace every branch of professional practice. The sound knowledge and experience thus acquired would add greatly to his efficiency and value in any special branch. For the railway engineer there was required a thorough knowledge of surveying and earthworks, the capacity to design bridges, earthworks, and tunnels, and a knowledge of the effect of floods and drainage. To this should be added some knowledge of architecture, and a taste for appropriate decoration. The dock and harbour engineer required, he said, much of the general knowledge of the railway engineer, with a vast amount of special knowledge. This included the laws which govern the tide, the set and speed of currents, their scour and silting; also questions relating to the trade to be accommodated, and the methods of dealing with the goods. He would also be required to be cognisant of such matters as harbours of refuge, piers, landing stages, lighthouses, forts, and hydraulic appliances. The water works engineer, in addition to his general qualifications, had to be familiar with the means of collecting information about rainfall, the method of gauging streams, the excavation of reservoirs, conduits, weirs, tunnels, and aqueducts. He must also be competent to superintend and design sewerage works. The mechanical engineer, the speaker continued, dealt with the most varied and numerous subjects of all the branches of engineering. He must understand the laws of motion, of heat, of liquids, and gases; he must be familiar with the strength of materials and the friction of surfaces. On railways he was responsible for the machine tools, engines, and locomotives. For docks he had to design the machinery for working the gates, the sluices, and the cranes. For water works he produced the pumping engines, sluices, valves, stop-cocks, &c. And so on through the entire series of works in which mechanism is employed. The mining engineer needed, in addition to a knowledge of railway and mechanical engineering, the information requisite for sinking shafts, draining workings, excavating and raising minerals, and preparing them for market.

Mr. Fowler then turned to the preparation required by a civil engineer to enable him to perform his work efficiently. This he classed under four heads: (1) General instruction, or a liberal education; (2) special education as a preparation for technical knowledge; (3) technical knowledge; (4) preparation for conducting practical works. He supposed a boy to start at fourteen years of age with a strong constitution, considerable energy and perseverance, and a fair education, together with a mechanical bias. The period from fourteen to eighteen should be devoted, he said, to a special education, including mathematics, natural philosophy, surveying, drawing, chemistry, mineralogy, geology, strength of materials, mechanical motions, and the principles of hydraulics. To these must be added considerable progress in French and German, even at the sacrifice of classical studies and pure mathematics. At the age of eighteen, assuming the boy to have fair abilities and more than average perseverance, three courses were open. He might be placed with a civil engineer for four or five years' pupilage, or in a mechanical workshop, or he might be sent to one of the universities. The choice would depend on the taste of the boy, the means of his parents, and other circumstances. If he followed either of the first two courses it would be necessary for him to continue his studies in mathematics, science, and foreign languages at the same time. If the latter course were adopted, the drudgery of learning to survey, to draw, and the like, must be passed through first. With a clever hard-working boy the most advantageous course might be to send him, from seventeen to eighteen, into a good workshop, then for three years for a university course, and finally into an engineer's office for his pupilage. This, of course, would require a boy of special ability and determination to render it a successful course. The office chosen for the pupilage to be passed in ought to be well organised and not too large; the engineer should be a comparatively young and rising man, and be accustomed to take pupils, who should be few in number, and bear some proportion to the number and extent of the works in usual course of construction under the engineer's direction. Here the pupil ceased to be a boy, and his future success or failure could no longer be directed by others, but depended upon his own abilities and industry.

Mr. Fowler also laid stress on the fact that the whole duties of the engineer were not comprised in the mere accomplishing of the objects entertained by his employers. It was his duty, he held, to advise those who consulted him whether the undertaking was one that would repay the expenditure which must be made upon it. The engineer was not merely a man of technical skill engaged to bridge the difficulties of capitalists, as a servant carries out the orders of his master; on the contrary, he was a member of an honourable and noble profession which could not lend itself to enterprises which did not give fair promise of being beneficial to the world, and to the advancement of civilisation.

In 1870 Mr. Fowler took part in a commission sent to Norway to examine the railways there. As is well known Norway has built a great length of railway which was constructed at a very small cost and is worked very cheaply. Now, at the date mentioned the Indian government were undecided whether to adhere to the broad gauge of 5 ft. 6 in., which had been adopted for the trunk lines, or to introduce a narrower gauge for the less important railways. A commission composed of General Strachey, Colonel Dickens, Mr. Rendel (now Sir A. Meadows Rendel), and Mr. Fowler, was, therefore, sent to Norway, for the purpose of acquiring information as to what gauge should be adopted in India, assuming that it was decided that a narrow gauge should in certain cases be laid down. The commission was received and accompanied by Mr. Carl Pihil, the experienced engineer of the Government, who had carried out all the railways in Norway. They travelled over the Dovre Fjld by carriole, passing over the ground on which a railway has since been constructed, and were thus able to see the nature of the works which would have to be carried out. The Norwegian lines are 3 ft. 6 in. gauge, and the rails and engines are both very light, the speed being usually quite slow. Mr. Fowler considered this gauge narrow enough, and the engines too light for economy. His colleagues, however, took a different view, and recommended 2 ft. 9 in. as the proper gauge for India.

Two reports, therefore, were made, one by Mr. Fowler recommending 3 ft. 6 in. gauge, and one by the other members of the Commission, recommending 2 ft. 9 in. The final decision of Government was between the two, but much nearer Mr. Fowler's opinion, viz.—a metre, or 3 ft. 3⅜ in.

It was understood that the question referred to the Commissioners was not whether narrow-gauge railways should be adopted in India or not, but, supposing a narrow gauge to be adopted, what gauge should it be. Mr. Fowler, from his long experience of the evil on the Great Western Railway, had very strong objections to breaks of gauge except when unavoidable. He would never permit an exceptional gauge in a link, or a possible link line, nor for short branches where exceptional plant would neutralise all saving. He considered that an exceptional gauge should be confined to a district of country where break of gauge is unimportant by reason of non-interchange of traffic, and even then he preferred to adopt a light railway on the standard gauge, except under very peculiar circumstances, which must be very rare indeed, when the narrow gauge would have some special advantages.

Last winter (1888-89) Sir John Fowler had the opportunity of verifying by actual inspection on the spot, the opinion he had formed as to the railway policy of India, and it is well known that he has expressed himself as having had his former conclusions strongly confirmed by his Indian visit.

Sir John visited Darjeeling to see the working of the 2 ft. 6 in. gauge mountain railway, ascending 8000 ft. by gradients of 1 in 27. This curious little railway has been laid on the fine road made to Darjeeling, and, being saved all expenses except that of permanent way, it is not surprising that a good dividend is earned, notwithstanding the fact that the engines can only draw less than twice their own weight up the incline. In this case the gauge and everything else are suited to the traffic, but unless the same circumstances were found the system could not be applied elsewhere with advantage.

Sir John was naturally much consulted, both professionally and otherwise, in India by the authorities on the subject of railways, docks, and water works, and was received everywhere with great distinction. His general impressions of India and its resources were of the most favourable character.

Fowler's career is that connected with Egypt. He went there, in the first instance, in search of health; and the connection thus accidentally formed lasted as long as Ismail Pacha remained in power. As is well known, that enterprising Sovereign threw himself heart and soul into the material improvement of the country. He had unlimited credit in the money markets of western Europe, and he aimed at restoring Egypt to its ancient position as one of the chief producing countries of the world. He brought about a wide extension of the irrigating system of the Delta, in order that crops might follow each other independently of the season of the year; he introduced sugar plantations and factories in Upper Egypt on a most extensive scale; he built several railways, and projected one southwards to Khartoum, which, if completed, would have been the key to Central Africa. He entered upon every scheme with the greatest ardour, and no sooner were the plans completed than he urged the giving out of the contracts and the commencement of the work. In Mr. Fowler the Khedive found the very man he wanted—one whose ability was only equalled by his rectitude. National prosperity, however, is not to be founded by railways, docks and canals alone. Its basis lies in good government and the just administration of wise laws; but it is not our business to go into the politics of Egypt further than to explain the condition of affairs when Mr. Fowler came in contact with them.

He landed in Egypt at the close of 1868. At this time the Suez Canal was within a year of its completion, and it was natural that Mr. Fowler should hurry to see it, even before fulfilling the avowed object of his visit of exploring the antiquities of the country. The trip was made under very favourable circumstances, the party including M. de Lesseps, M. Voisin, the Duke of Sutherland, Sir Richard Owen, General Marshall, the Marquis of Stafford, Mr. W. H. Russell, and others. The works from Ismailia to Port Said, and the harbour works at Port Said, were well advanced, but between Ismailia and Suez nearly one-third, or twenty-five million cubic yards of excavation, remained to be executed. The survey occupied three days, and included the whole length of the canal, everything being explained by M. de Lesseps with the greatest kindness, and the various points being discussed without reserve. At the request of the editor of the *Times* Mr. Fowler addressed a long letter to that journal giving a full account of the state of the works and criticising the prospects of the company. This letter appeared on February 18, 1869, and was made the text of a leading article which pronounced it to be a fair and final summary of the subject by an English engineer of the highest eminence and repute.

In the spring of 1869 the Prince and Princess of Wales visited Egypt. When about to make the journey up the Nile the Prince invited Mr. Fowler and Professor Owen to join the party, which was embarked on five steamers and dahabeahs. Nothing could be pleasanter than to make the excursion under such conditions, as every arrangement was made for the Royal party to see the objects of interest in the country, both ancient and modern. Of course Mr. Fowler had to pay the usual penalty of fame, and to be prepared to suggest the probable methods employed by the Egyptians in raising large stones for the pyramids and temples, and in cutting and polishing the greenstone and diorite statues. At Thebes his engineering resources were severely tried by the Prince's cross-examination as to the manner in which the colossal statue of Rameses II., weighing 888 tons, was brought from the quarry near Assouan to its present position at Memnonium on the plain of Thebes. The excursion proved to be most enjoyable.

Before Mr. Fowler returned home he had several interviews with the Khedive, explaining to him his views concerning the Suez Canal, the irrigation schemes, and many other matters in which Ismail Pacha was interested. The outcome of this was that he accepted the position of consulting engineer to the Khedive and the Egyptian Government, a post which he held for eight years—that is, until the abdication of that ruler. The office involved yearly journeys to Egypt, the first being in the latter part of 1871, and required Mr. Fowler to personally investigate all the great undertakings then in hand. The most important matter presented to him for solution was the projected Soudan Railway. It is needless to say that, although carried out, or recent Egyptian history would have been greatly changed, while thousands of British soldiers and millions of money would have been saved.

Mr. Fowler, before deciding between the two possible routes by the Nile Valley and by Souakim-Berber, had long interviews with General Gordon, and also with the governors and other persons acquainted with the country to be traversed. The Nile Valley was ultimately chosen, and the decision ratified by the Khedive and his ministers. The surveys were commenced at once, and when completed the Khedive, with characteristic promptitude, instructed Mr. Fowler to obtain a contract for the work. This was accordingly done, and on February 11, 1875, the works were commenced at Wady Halfa with great ceremony in the presence of Mr. Fowler, the governor of the province, the Cadi, and other notables, bullocks being slaughtered as part of the religious observances. The abandonment of the railway, and all the disasters which followed it were keenly felt by Mr. Fowler, who fully believed that had Khartoum been thus connected with Cairo the turbulent native tribes could have been overawed, and a great economy would have been effected in the long run. Unfortunately it is not given to man to read the future, and when matters went wrong in Egypt the expense of the railway seemed too great for the resources of the country.

Although this railway was not completed, and has passed for the moment out of public notice, yet it is a matter of certainty that sooner or later it will be constructed. The eyes of nearly all European nations are concentrated on Africa, and many are striving to secure a firmer foothold on the continent with a view to gaining a share of the future trade which is anticipated. It is certain that when Egypt attains the position which is sure to follow upon a few years of good government, there will be a revival of the old ambitions, and she will turn her attention southward, with that craving for extended sovereignty which is the characteristic of all healthy communities. It will, therefore, be interesting to give a few facts regarding the route, length, and cost of the line which must be made if the flood of Arab invasion is to be permanently dammed. Sir John Fowler always held the opinion that our difficulties in the Soudan came from the undecided attitude we took up. The native tribes could not be neutral; they were obliged to side either with the English or the Mahdi. But the former declared that they had not come to stay; they came to rescue Gordon, and when that was done they would retire, and leave the entire population "to stew in their own juice." This promised to be so highly flavoured with Mahomedan vengeance that the tribes were obliged to cast in their lot with the successor of the Prophet, and fight against the invaders. In the days of Ismail Pacha the Soudan was ruled by the shadow of the authority which existed at Cairo, and Sir John Fowler holds that the same conditions would recur if the railway were completed.

The southern terminus of the line was to be at Metammeh, on the left bank of the Nile, immediately opposite Shendy, 16 deg. 14 min. N. latitude, and 32 deg. 25 min. E. longitude. Shendy is equidistant between Berber and Khartoum, and about 99½ miles from each. It is moreover the converging locality for the camel routes from Khartoum and the White Nile district, from Hamdal, Souakim, and the Red Sea, and from Aboo Kharraz and the Blue Nile. There is good navigation between Berber and Khartoum for ten months in the year, and the obstructions which exist in the low-water channel would not be difficult to remove or lessen. The northern or Egyptian end of the line was fixed at Wady Halfa, at the second cataract. Commencing at the foot of the cataract on the right bank of the river, the line followed the general course of the stream as far as Kohé, this side being chosen to avoid the drift sand from the Nubian desert. At Kohé the line crossed the Nile, and then followed the right bank as far as Dabbe. Here the Nile makes a long detour, and consequently the projected line struck across the Bahiuda desert to its terminus.

The following are the lengths:

	Miles.
Wady Halfa to Kohé	160
Kohé to Ambukol	216
Ambukol to Shendy	176
	552

works of magnitude except the Nile crossing. When practicable it kept to the villages and cultivated lands on the banks, but sometimes it took an inland course amongst the mountains to avoid expensive works, and sometimes it traversed deserts to cut off bends of the river. The gauge was fixed at 3 ft. 6 in., the same as the Norwegian railways, but with a heavier rail of 50 lb. to the yard; the maximum gradient was 1 in 50, and the minimum radius of curvature 500 ft. The cost, including stations, sidings, quays or landing places, rolling stock, workshops, and all expenses required to complete the line ready for traffic, was estimated at four millions sterling, or 7240*l*. a mile. Of this amount five-eighths would have been spent abroad and three-eighths in Egypt.

It will be noticed that the railway was to start at the second cataract, some 550 miles, as the crow flies, from Cairo. The Nile forms a natural roadway between the two for the entire distance, except for some three miles at Assouan, where the first cataract occurs. To enable steamers and dahabeahs to pass from the lower to the upper level of this cataract, Mr. Fowler conceived the idea of a ship incline, and in company with Sir William (now Lord) Armstrong and Mr. Rendel he went to the site. The necessary surveys, examinations, and estimates were made, and on the return to Cairo Sir W. Armstrong offered to undertake the work, and his proposals were approved. But like many other projects of that time in Egypt, the plan was frustrated by the interference of jealous foreign rivals, and nothing was done.

The plan contemplated the construction on the right bank of the canal of a ship railway 3 kilometres in length, commencing at the bottom of the cataract in the river channel, about 5 kilometres south of Assouan, and terminating at the top of the cataract in the harbour of Shellal. The boats to be transferred were to be floated upon a cradle constructed to run upon the railway, and to be hauled over land by hydraulic engines of 400 horse-power, placed near the centre of the railway. The water to work the engines was to be pumped at a high pressure by a pair of large stream wheels carried upon pontoons, and driven by one of the smaller rapids at the lower end of the cataract. The total length to be traversed over land by the boats was 2950 metres at low Nile, and 2300 metres at high Nile. The estimate of the cost of the incline with machinery, workshops, wharves, and all expenses required to complete it ready for traffic, was 200,000*l*.

One of the first matters claiming Mr. Fowler's attention on undertaking the duties of consulting engineer was the organisation of the existing railways, and to this he devoted much time on his first official visit in 1871. As a preliminary he employed Mr. D. K. Clark to obtain for him full details of the rolling stock and plant. With this information before him, Mr. Fowler was able to advise great changes in the direction of simplicity and economy, most of which were carried out.

The management had previously been of a most unsatisfactory condition. In the year 1869 the expenses per train mile amounted to 7s., of which the locomotive power figured for 3s. 5d. Many other items were needlessly high, and were increased by the practice of keeping duplicate sets of accounts, more or less imperfect, in French and Arabic. Mr. Fowler considered that the expenses could be well cut down to 4s. 6d. per mile, or 36 per cent. of the earnings. This small percentage was due to the very high traffic charges, particularly on the transit railway which conveyed the P. and O. Company's passengers across the isthmus; on this line first-class passengers were charged 4¾d. per mile, and second-class 2½d.; accelerated goods were charged 4½d. per ton, and unaccelerated 1d. per ton per mile.

In the same year visits were made to Upper Egypt to examine irrigation works and sluices, and to Suez to determine matters connected with the docks there. M. Duport, on Mr. Fowler's recommendation, was appointed engineer in charge of the new Alexandra Docks, a post which he filled in a highly satisfactory manner till the completion of the works.

In the following year, 1872, the most important matter for consideration was the sugar plantations and factories of the Khedive. Already several millions sterling had been spent upon them with but poor returns, and the time had come when some alteration in working must be decided upon.

To aid him in forming his judgment, Mr. Fowler secured the valuable assistance of Mr. (now Sir Frederick) Bramwell and Dr. Letheby. The result was that reports of the most exhaustive character were presented to the Khedive, and formed a valuable guide for all future operators. The Khedive, however, was too sanguine, and the works were established too rapidly and on too extensive a scale. Possibly the climate was also not quite suitable for sugar cultivation. The broad result was a very serious loss of money to the Government.

During the course of the investigation into the conditions of the sugar estates, several interesting facts, worthy of being placed on permanent record, were demonstrated. It was found that the soil of Egypt, which, of course, is entirely Nile deposit, consists of a large amount of fine sand, mixed with an unctuous clay, in the form of minutely divided double silicates of alumina and iron, together with fine oxides of iron, alumina, potash, alkaline silicates, soluble silica, and a fair proportion of carbonates of lime and magnesia. The soil is in such a minute state of subdivision that it readily yields its most important constituents (silica, phosphoric acid, and potash) to the growing crops. For the cultivation of sugar it is necessary to equalise the excess of potash by the application to the land of more phosphoric acid, and to make up for the deficiency of nitrogen by the addition of ammonia. Analyses were also made on another occasion of the Nile water to determine whether it had, when used for irrigation purposes, any manurial value beyond that due to the suspended mud. The samples were taken about the middle of the months of June, July, August, September, and October. It was found that in each case the water contained a considerable quantity of nitrogenous matter in the form of actual ammonia, as well as ammonia derivable from organic matter. The proportion of actual ammonia was largest in July and smallest in August. The organic ammonia was smallest in the August sample and largest in September. Taking the whole of the ammonia derivable from 100,000 parts of water, the quantity ranged from .0114 parts in the August sample to .0271 in the sample collected in June. These are remarkably large proportions when we consider that the Nile does not receive anything in the nature of sewage or ordinary town drainage, for they are largely in excess of the proportions found in the River Thames at Hampton. The properties of soluble saline matters in the Nile water range from 13.443 parts per 100,000 in October to 18.8 parts in June. The chief ingredients in these saline matters are the carbonates and sulphates of lime and magnesia, but there is also a notable quantity of soda and potassa, as well as a trace of phosphoric acid. The sedimentary matters in the several samples taken amounted to 6.915 parts per 100,000 of water in June, and to 149.157 parts in August; and the proportions of organic matter in the deposit ranged from .829 parts to 18.414 parts. The results show that the water of the Nile is remarkably rich in fertilising matters, for not only does the water contain in solution a notable quantity of ammonia, nitrogenous organic matter, and the soluble silicates of potassa and soda, as well as a trace of phosphoric and nitric acids, but it also contains in suspension a large amount of sedimentary matters which are charged with phosphates and alkaline silicates.

The most important Egyptian question submitted to Mr. Fowler was that of irrigation. Upon this depends to a great extent the fertility of Lower Egypt, for although the annual inundations can be depended upon to give the land one thorough watering, there are many crops that need to be watered several times and at different seasons of the year from that at which the flood comes. Immense irrigation works were constructed by Mehemet Ali, with canals running through the delta and the land on either side of it. For a considerable part of the year these canals served their purpose fairly well, but at the period of low Nile many of them became useless because they were at too high a level. This does not arise from any error of the designers, but from the fact that the barrage, which was built to maintain a minimum depth of water in the river, did not prove capable of resisting the required head. Hence it was necessary to allow the river to fall below the proposed level. Under these conditions Mr. Fowler was instructed (1) to prepare alternative plans for placing all the cultivated and cultivable lands of Lower Egypt in a position to be irrigated at any time of the year without pumping; (2) to devise an improved means of introducing flood water several times during high Nile upon any required lands on the left bank of the Nile, and of discharging it at pleasure without interference with other lands; (3) to prepare a scheme for the construction of a ship canal between Alexandria and Cairo. Mr. Fowler proposed as alternative projects under the first head; (1) a high level canal on the right bank of the Nile; (2) a high level canal on the left bank of the canal; (3) the completion of the present barrage or the construction of a new one. None of these proposals were then carried out, but during the past few years, under the superintendence of Colonel Sir Scott Moncrieff, the barrage has been repaired to such an extent that it will hold the water up to 3 metres, instead of 4.5 metres, as contemplated by Mr. Fowler. The methods employed in the repair of the barrage followed the lines laid down by Mr. Fowler, but were on a less extensive scale, as the pressure to be resisted was less, and there was greater difficulty in obtaining money than during Ismail Pacha's time. The deficiency of head is made good by pumping into the higher canals.

The second undertaking required a canal starting very high up the Nile, and following the course of the Bahr Yousuf, but it presented no features of special engineering interest, and was not attempted. The third, the ship canal, was a subject in which Ismail Pacha took the greatest interest. He found that the effect of the Suez Canal was to divert the traffic from the capital, and to take the stream of passengers through the country without adding anything to its wealth or importance. He, therefore, conceived the idea of making Cairo into a seaport, with easy access to the Mediterranean. Mr. Fowler worked out a combined irrigation and ship canal from the Mediterranean to the Red Sea, by way of Cairo. This canal would have been a formidable rival to the Suez Canal, in so much as the dues derivable from the irrigation water would have enabled the tolls on ships to have been reduced to a very low figure. In the negotiations which subsequently took place with the Suez Canal Company, the possibility of the second canal being made, served as a powerful lever in the hands of the English party.

Although so many of Mr. Fowler's Egyptian schemes were not carried out, we must not regard them as wasted effort. For thousands of years Egypt has been the prey of conquerors of many races and creeds. Probably for the first time in her history she is in the hands of a power which has no selfish aims, and thinks solely of the good of the inhabitants. Under such conditions she must prosper, and the time is certain to come when many of the ambitious schemes of her late ruler will become possible of realisation. At that moment the reports and drawings of Mr. Fowler will be turned to as the key of the plans to be adopted.

Space does not permit us to particularise all the great works in Egypt with which Mr. Fowler was concerned, such as the construction of steamers for the Khedive, surveys for a railway to Harrar, and many others. For nine years he made periodical visits to the country, and became greatly interested in its fortunes. The connection was broken, however, when Ismail Pacha was made to abdicate, and a new era of economy was introduced. Egyptian credit was almost exhausted, and what little was left was destroyed by the revolt of Arabi Pacha. A few years later (1885) the Queen, on the recommendation of the Marquis of Salisbury, created Mr. Fowler Knight Commander of the Order of St. Michael and St. George "for important services and guidance to Her Majesty's Government in connection with Egypt."

A curious example of the way that the engineer may be useful in averting political troubles is found in one of the incidents of Mr. Fowler's career. The Italian premier, M. Minghetti, had disagreed with Garibaldi on the question of the rectification of the Tiber. The popular patriot was powerful at the time in Italy, and wielded an influence which the Government did not care to have exercised against themselves. At the same time they did not feel able to accept his views on the particular question before them. Mr. Fowler was at that time at Cairo on one of his Egyptian visits, and it was decided to submit the matter to him. He was accordingly summoned to Rome, and was fortunately able to reconcile the differences of the two parties, to the great relief of the Government.

We now come to the Forth Bridge, the best known of all the works with which Sir John Fowler has been associated, and one which at the present moment is engaging the attention both of the general public and of engineering experts in all parts of the world. Sir John lays no claim to be the sole author of the design which was the joint outcome of four minds, all bent on discovering the best and cheapest means for carrying a railway over the Firth of Forth. Most people will remember that when the Tay Bridge was destroyed, preparations were being made, and were actually commenced, for bridging the Forth. Sir Thomas Bouch had designed a suspension bridge for the purpose, and an Act of Parliament had been obtained authorising its construction. The failure at the Tay at once threw doubts upon the safety of the most ambitious project, and the works were stopped. Subsequent investigation showed that the proposed bridge could not have been a satisfactory one.

A bridge across the Forth offered so much advantage to the railway companies forming the east coast route to Scotland that, after two years, the idea was revived. On February 18, 1881, the four great railway companies concerned, the Great Northern, the North-Eastern, the Midland, and the North British, wrote to their consulting engineers—Mr. T. Harrison, Mr. W. H. Barlow, and Mr. John Fowler, associated with Mr. B. Baker — propounding two questions for their joint opinions. They were asked to consider the feasibility of building a bridge for railway purposes across the Forth, and, assuming the feasibility to be proved, what description of bridge would be most desirable to adopt. The matter involved so large an expenditure and contained so many novel issues that it needed to be approached with the greatest possible care. It was fairly well known how many types of bridge there were to select from for such a site;—these were (1) Mr. Bouch's original design; (2) a stiffened suspension bridge; (3) a second form of stiffened suspension bridge; (4) a cantilever bridge. Calculations of weight and cost were made for each type of bridge and were discussed by Messrs. Harrison, Barlow, Fowler, and Baker, with the general result that the cantilever type was chosen. A report was made to the railway companies on May 4, 1881, embodying the result of the deliberations, and pointing out that the cantilever principle offered a cheaper and better solution of the problem than any other. The report did not enter into the details of construction; indeed it could not be said to give even the broad features, other than those which are involved in the use of the cantilever. These still remained to be elaborated in council, and it was only by united discussion that the original plan developed into the final design. Although the type of the bridge is very ancient there were many features in it which were open to consideration, and to differences of opinion, and at each meeting of the engineers new ideas were propounded, and novel methods of overcoming difficulties were mooted. After most elaborate investigations and calculations the structure gradually, by a process of evolution or development, assumed its present form.

The design being settled and the execution decided upon by the associated railway companies, the carrying out of the work was entrusted to Mr. Fowler, in conjunction with his partner, Mr. Benjamin Baker.

The Parliamentary fight had been exceedingly stubborn, for great interests were at stake. Hitherto the London and North-Western and the Caledonian companies have enjoyed a great advantage in carrying the Scotch traffic to Perth and the Highlands, in consequence of the east coast traffic having to traverse the circuit from Edinburgh *viâ* Larbert and Stirling to Perth. But when the bridge is opened this advantage will disappear. A very strong hybrid semi-public committee was appointed, with Lord Stanley, of Preston, the present Governor of Canada, as the chairman. Engineering evidence was brought forward to condemn the structure, and every possible description of hostile evidence for shipping interests was adduced against it, and made the most of by eminent counsel, who both in speeches and cross-examination strove to the utmost to prejudice the undertaking. But at the close of the case the committee were unanimous in favour of the Bill, only stipulating that the Board of Trade should maintain a general inspection of the works during construction. It was finally arranged at the suggestion of Mr. Fowler that the inspectors should report to Parliament every three months as to the progress of the bridge, and the quality of the materials and workman-

ships. These reports, made by General Hutchinson and Major Marindin, have appeared regularly in our columns, and all have spoken in the highest praise of the way in which the undertaking was being carried out.

Sir John Fowler and Mr. Baker have kept a personal and continuous control over the entire operation of building the bridge, and have superintended the series of processes, from the rolling of the plates to the closing of the rivets. They have further employed several distinct staffs of assistants for the purposes of (1) surveying and foundation work; (2) for working drawings; (3) for inspecting plates at the mills; (4) for inspecting the rivetting; and (5) for the fitting and erecting. Mr. Alan Stewart was chief of the staff in Westminster, where all the detailed drawings and calculations were made. The resident engineer was Mr. Cooper, who entered Mr. Fowler's office in 1863, and has remained there ever since. Mr. Tuit, Mr. Lilliquist, and Mr. Carey, and other engineers of exceptional ability were also on the engineers' staff. The contractors were selected on account of their previous experience. Mr. Phillips had had great experience in bridge building; Sir Thomas Tancred and Mr. Falkiner in large contracts and the organisation of labour; and Mr. Arrol had shown on previous occasions remarkable ability and resources. In the early days Mr. Phillips took an active part, but in the preparation and erection of the steel Mr. Arrol took the leading position, and he was ably seconded by Mr. Biggart, Mr. Moir, Mr. Westhofen, Mr. Harris, Mr. Scott, Mr. Bakewell, and others.

Having brought this series of sketches of incidents in the career of Sir John Fowler up to the commencement of the Forth Bridge, we do not propose to carry it further. In the columns of this issue will be found full details of the design and construction of that magnificent work. The bridge, however, has not monopolised the whole of Sir John Fowler's time and attention; he has been connected with many other important works in the meantime, besides fulfilling his standing engagements. Sir John became consulting engineer, on the death of Mr. Brunel, to the Great Western Railway, and besides this and many smaller undertakings, he is consulting engineer to the Great Northern, the Brighton, and Highland railways.

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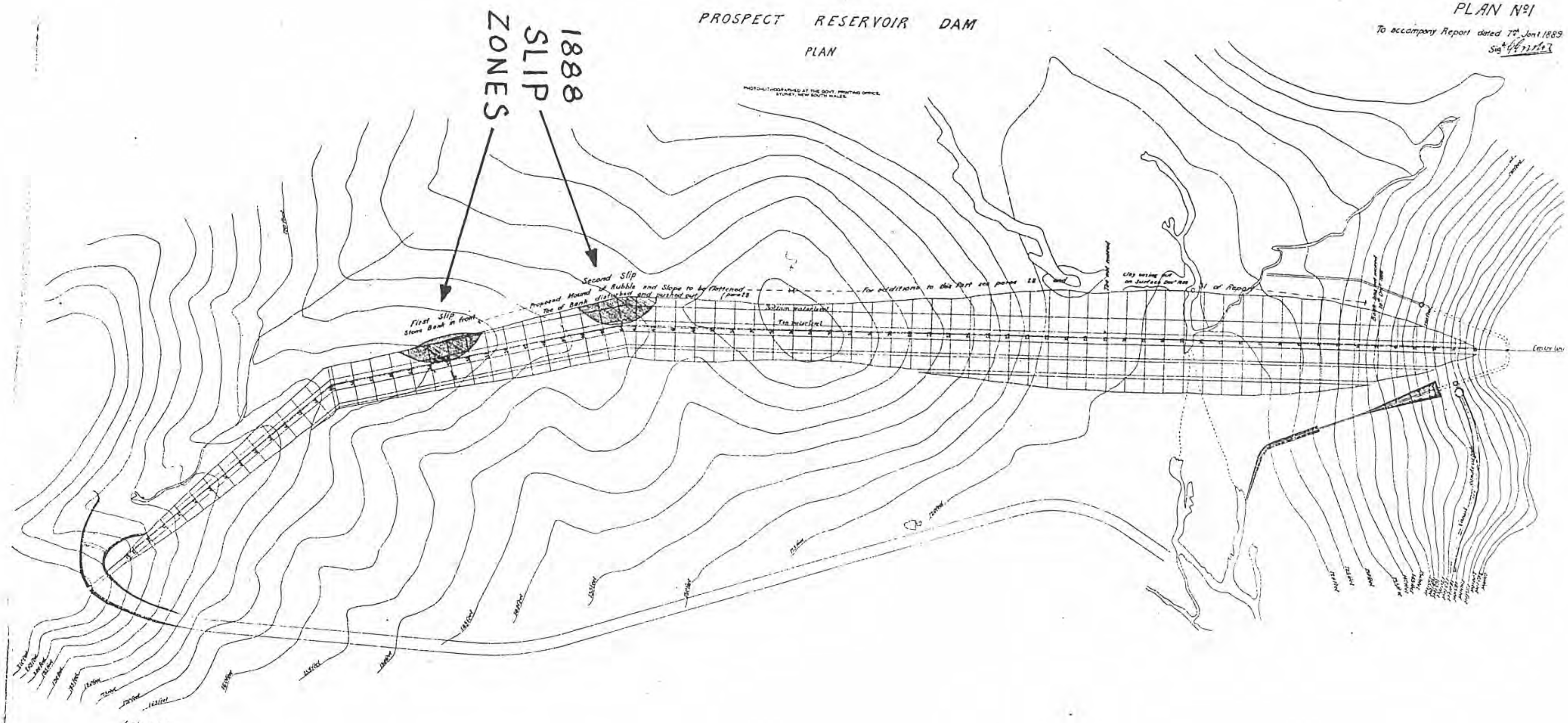
Laid upon the Table and ordered to be printed and appended to the papers previously laid upon the Table.
8/5/89.

PROSPECT RESERVOIR DAM

PLAN

PLAN No 1

To accompany Report dated 7th Janr 1889



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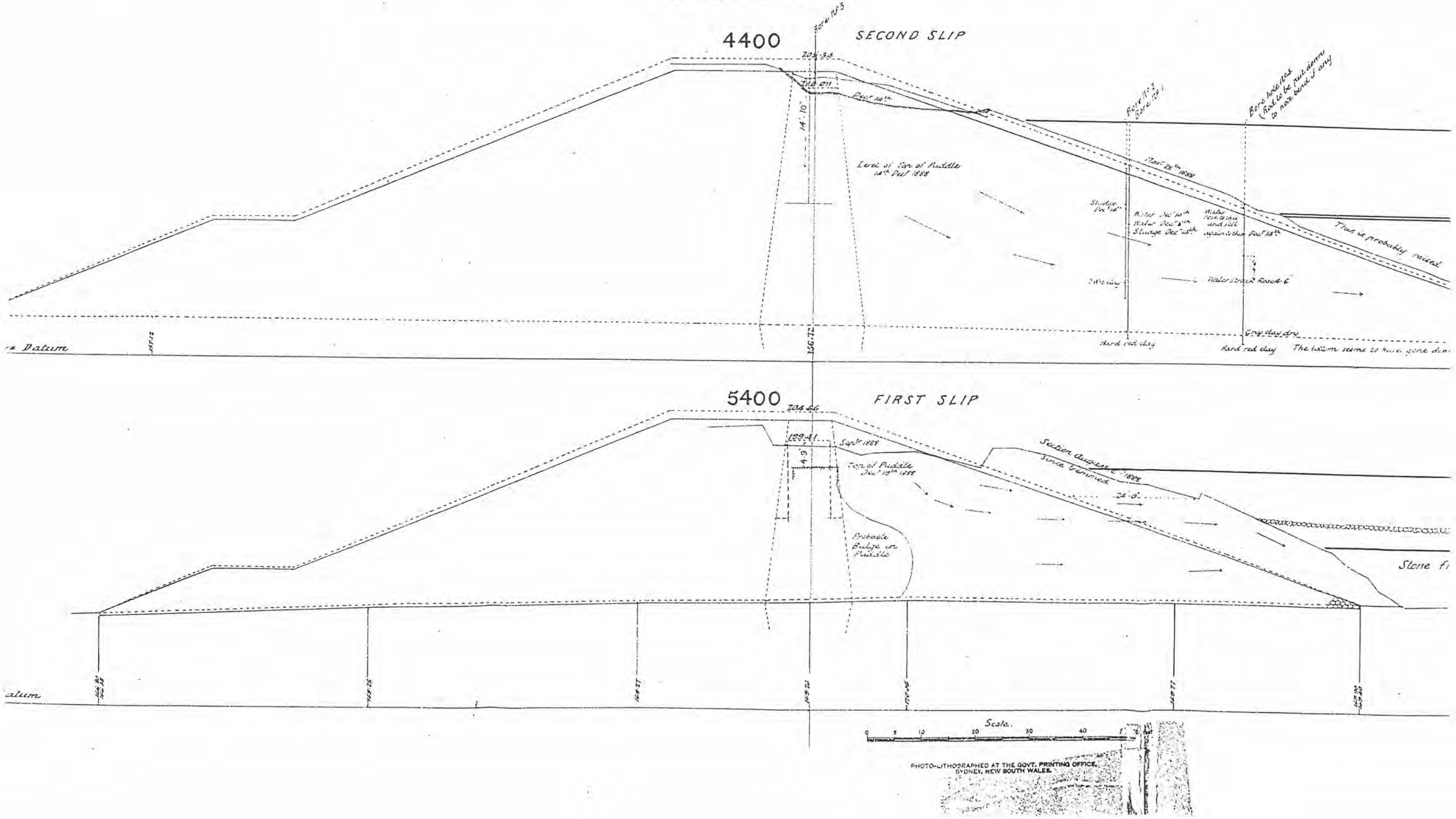
PROSPECT RESERVOIR

CROSS SECTIONS SHEWING MOVEMENT OF EMBANKMENT

SCALE 10 FEET TO ONE INCH



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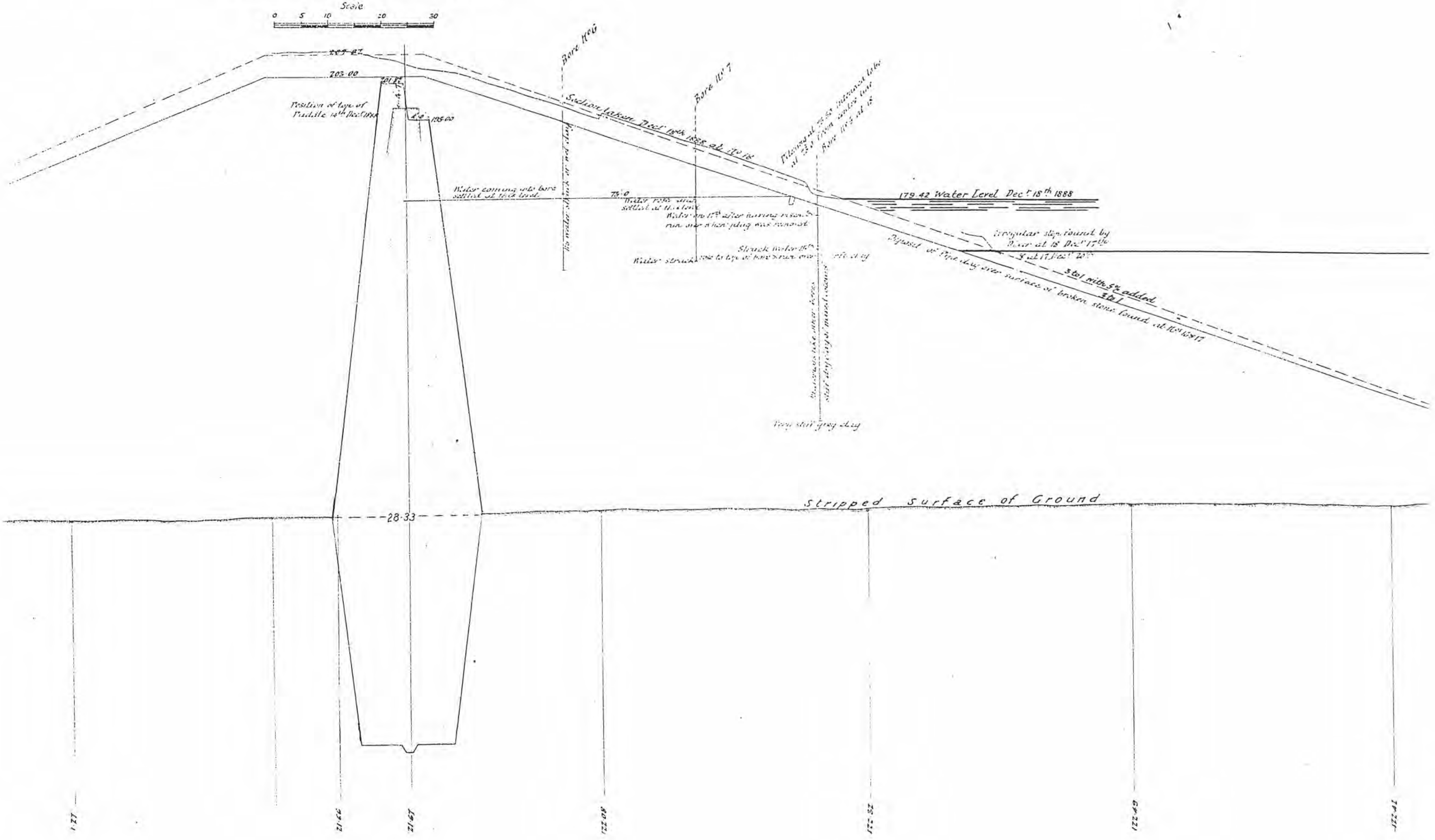
Section at 18

To illustrate state of Dam at T.Ss 16 to 19



1887–8.

LEGISLATIVE ASSEMBLY.

NEW SOUTH WALES.

SYDNEY WATER SUPPLY.

(REPORT ON THE PROSPECT DAM BY MESSRS. BISHOP, BENNETT, AND WHITTON, C.E.'S.)

Ordered by the Legislative Assembly to be printed, 20 *June*, 1888.

F. A. Bishop, Esq., C.E., to The Secretary for Public Works.

Sir,

130 Phillip-street, Sydney, 16 June, 1888.

Being honored with your instructions to examine and report upon the present condition of the Prospect Dam, I beg herewith to foreshadow my final conclusions by saying briefly that I have most carefully and diligently applied myself to the task of acquiring information ranging from the smallest details to matters appearing most important.

To the puddle trench I have given especial attention, endeavouring to acquaint myself with all the facts to be obtained in connection with its excavation, with the character of its bottom, and with its contents when refilled. I have also most carefully examined the quality of the material entering the embankment, the method of construction, and the supervision under which the work had been done.

I saw no disposition on the part of any of the officers in charge of the dam to conceal anything. All must have evinced most lively interest in the work; for the thoroughness of the construction of the dam attests their care. I could not find anything to cause in my mind distrust as to the integrity of the embankment. I believe that it will prove entirely stable.

The subsidence lately noticed is measurably inherent in structures of the kind and of such magnitude. All of the movements, in my opinion, can be accounted for. This pile of earthy matter requires time for complete adjustment of its atoms, when it will rest. It is not a confused heap of rubbish hastily thrown together, but composed of suitable materials intelligently placed.

Believe me, Sir, the Prospect embankment is amply able to support the burden appropriated to it.

I have, &c.,

F. A. BISHOP, C.E.

F. A. Bishop, Esq., C.E., to The Secretary for Public Works.

Sir,

130, Phillip-street, Sydney, 16 June, 1888.

I have the honor, in pursuance of your instructions of the 2nd instant, to forward to you a report *ad interim* on the condition of the Prospect Dam, to assure you of its perfect stability.

Upon the termination of my duties in the Commission, to which you have been pleased to appoint me—they appearing to be matters of great urgency—I shall hasten to condense and arrange the volume of data which I have obtained relating to said embankment, and at the earliest moment will lay my conclusions before you.

I have, &c.,

F. A. BISHOP, C.E.

REPORT ON SLIP AND SUBSIDENCE, PROSPECT DAM.

In accordance with previous instructions, I accompanied Messrs. Whitton and Moriarty to inspect the Prospect Dam on the 24th May.

Attention had been drawn to two defects:—That a narrow opening in few places exceeding an inch along the top of dam on inner face of puddle trench. Second,—the slip between 51 and 55 chains at a point where the finished height of dam will be 34 feet.

On the 8th June I had another opportunity of examining this work when accompanying the new Board on their inspection. It was then found that the crack along the central deepest part of the dam had developed into a sudden settlement of the puddle, amounting to 10 inches. On the preceding Saturday the slip at 51 and 55 chains—though very slightly moving—had only sunk 7 inches, and moved forward 9 inches at the maximum point, but had not extended on either side.

At the crack in central part of dam a trench 8 to 10 feet deep had been excavated, exposing the material of which the inner slope of dam was composed—which proved to be a compacted mass of mixed clays of a superior character, which stood perfectly upright and stiff. The

2320 NEW

1888.

LEGISLATIVE ASSEMBLY.

NEW SOUTH WALES.

SYDNEY WATER SUPPLY.

(FURTHER REPORTS AND MINUTES AS TO THE CONDITION OF THE PROSPECT DAM.)

Ordered by the Legislative Assembly to be printed, 12 *and* 13 *December*, 1888.

Engineers-in-Chief J. Whitton and W. C. Bennett to The Secretary for Public Works.

Prospect Dam.

Sir, Sydney, 11 December, 1888.

We know of no way of ascertaining whether the puddle-wall has broken or not above the level of the water in the reservoir, but so long as the water is retained in the reservoir without any discharge through the embankment the puddle-wall up to that height may be considered perfectly safe.

We have no reason to believe that the puddle-wall is not in perfect order, but the fact can only be determined by the water being admitted to a greater height. The officers superintending the work only could give a reliable opinion on this point, and to strip off the inside slope of the dam to examine the condition of the puddle-wall would be fraught with the greatest possible danger to the whole embankment.

On carefully considering the steps to be taken with reference to the disturbance No. 2 (which can hardly at present be called a slip) we think that weighting the toe with stone in a similar manner to that done to No. 1 slip will be the best course to adopt under present circumstances.

If the puddle-wall has been properly made we have every confidence in the ultimate security of the dam.

We have, &c.,
JOHN WHITTON.
WILLIAM C. BENNETT.

Minute by Mr. Assistant Engineer Hickson.

Harbours and Rivers Branch, Sydney, 12 December, 1888.

Subject:—Forwarding Mr. Williams' report and plan for remedying the defects in the Prospect Dam.

I FORWARD herewith, for the information of the Minister, a plan and report of Mr. Williams, showing how he proposes to remedy the defects in the Prospect Dam. It is, in my opinion, nothing more or less than a new dam inside the present one, with this serious defect, that instead of its being founded on a solid foundation it is founded on what is supposed to be an unsound inner slope.

If this inner slope is fit to carry the structure Mr. Williams proposes it is certainly fit to stand by itself, and therefore is quite safe in its present form. 88/2452.

Mr. Williams proposes removing a portion of the top of the present dam, which "he considers a source of danger and quite unnecessary," and place it on the inner slope, or, in other words, he takes this material off the part of the dam which has never shown any sign of settlement and places it on a part that has sunk, and may, if it is proved to be made of inferior material, sink more.

To carry this out Mr. Williams proposes running the water out of the dam for three months, and arranging the time when the rivers are in full flood, so as to keep a constant supply of water to Sydney. Mr. Williams does not explain how this time is to be arranged. I fear it would be an exceedingly difficult thing to do, and rather a dangerous experiment as regards the water supply for Sydney. I am confident under no circumstances should a drop of water more than is required for Sydney be allowed to escape out of the reservoir.

I recommend that these papers be sent to the gentlemen now engaged by the Minister reporting on this dam.

B.C., Under Secretary for Public Works. ROB. HICKSON.

Submitted.—J.B., 12/12/88.

Most undoubtedly; and all the original plans and papers as well. In fact everything on the subject, and every source of information, should be placed at their disposal. My object is to get the fullest inquiry, untrammelled in every respect, no matter what the result may be.—JOHN SUTHERLAND, 12/12/88.

[*Enclosure*.]

Members: T.T.Ewing, J.N.Brunker, H.Clarke, F.G.Crouch, G.Day, W.Henson, A.Kethel, M.McFarlane, R.Stevenson.

The SC considered that Harrison's selections should not have been forfeited, and his case is recommended. The Report was adopted by a later SC on this case (item 485).

470. SC on conditional purchase of James Connelly, Tamworth. (29.11.1888)
Members: R.H.Levien, A.Bowman, J.N.Brunker, S.Burdekin, M.Chapman, G.Day, W.S.Dowel, T.H.Hassall, R.Stevenson, W.C.Wall.

One meeting was held, but no Report can be traced. Although SCs on Connelly's selection were appointed or renewed on five further dates between 1890 and 1896, no Report eventuated. (See also items 494, 549 and 586)

471. Commission of inquiry into the condition of the Prospect Dam; Report. (4.12.1888) (7.1.1889 + 11.1.1889 + 30.1.1889)
NSW Pp. 1889 (v.4 - First Session) 779-869. fold. plans.
Members: G.Gordon, R.L.Mestayer.

The two members submitted separate Reports, and later separate supplementary Reports in the form of letters to the Secretary for Public Works.

Gordon found that the contractors had carried out work on the dam as nearly as possible according to the specification. The dam itself was considered unstable because of the "clayey" nature of the inner slope, and the imprisonment of an excessive quantity of water during construction. A thorough examination of the bank is considered essential.

Mestayer's Report also attributes the movements that had occurred to excess water in the embankment acting on the inferior materials.

Both members concur in their supplememtary Reports that emptying of the reservoir is out of the question, and stress the need for a thorough examination of the bank. Further discussion concerns Gordon's suggested flattening of the slope and a difference in estimates of likely costs.

472. SC on Whaling Road, North Shore. (10.12.1888)
Members: R.H.Levien, G.Day, W.S.Dowel, F.Farnell, M.Garrett, J.Haynes, J.Hurley, I.E.Ives, F.Smith, J.M.Toohey.

Although one meeting was held, no Report can be traced. Reports were issued by two other SCs on this case (items 387 and 525).

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CHECKLIST OF ROYAL COMMISSIONS SELECT COMMITTEES OF PARLIAMENT AND BOARDS OF INQUIRY

by

D. H. BORCHARDT
M.A., Dip. N.Z., Lib. Sch., A.L.A., F.L.A.A.

PART IV
NEW SOUTH WALES
1855 - 1960

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WATER BOARD

PROSPECT DAM

STABILITY INVESTIGATION

STATUS, INVESTIGATION AND IMPACT AND CONCEPT REPORTS

(STAGES I, II AND III OF INVESTIGATION)

CONSOLIDATED VOLUME OF SECOND EDITION OF REPORTS
UPDATED AS AT 20 NOVEMBER 1991

SNOWY MOUNTAINS ENGINEERING CORPORATION LIMITED
COOMA NSW AUSTRALIA

SMEC

NOVEMBER 1991

3. DESCRIPTION AND HISTORY

3.1. DESCRIPTION OF DAM AND ITS ASSOCIATE WORKS

The dam is an earthfill dam on Prospect Creek, a tributary of Georges River. The damsite is almost due west of and about 34 km from Sydney's central business district. The reservoir it impounds is an important component in the water supply to Greater Sydney.

The dam is shown in Photographs I-1 and I-2 and in detail on the Board's drawing 1084/23 (Figure I-1). It is a zoned embankment with a thin impervious puddle clay core. Its maximum section, which is at the original creek bed close to the left[1] abutment, has a height of 26 m. The dam is over 2 200 m long. Its total volume is just over 2.7 million cubic metres, which includes a recently constructed downstream stabilising fill. The dam has a crest level of EL 62.36 m and a crest width of nearly 10 m. Its upstream slope is nominally 3 horizontal to 1 vertical (but see later in this section for description of additional upstream fill) while the net slope of the downstream face of the stabilising fill built in the late 1970s, is roughly 6 to 1, after allowing for the berms in the face. The dam's alignment, which is generally just north of east, consists of three distinct straights and gives it a generally concave downstream shape. The two intersection points have been called "dog-leg" corners by the several investigators over the years.

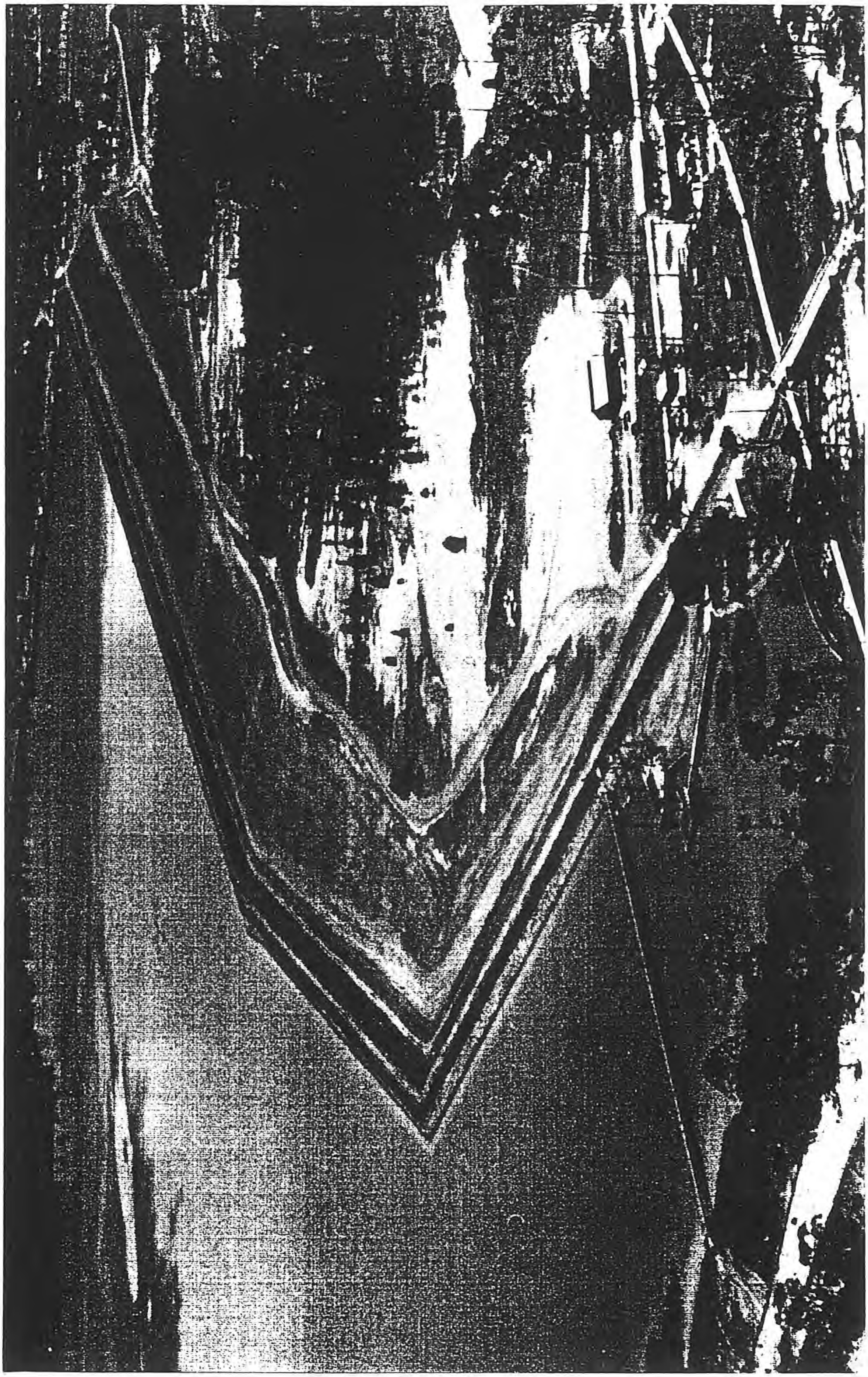
The dam is wholly located within the Bringelly shales of the Wianamatta Group. Across the original bed of the Prospect Creek, the dam is actually founded on alluvial clays (defined as fluvial deposits by the Geological Survey of New South Wales) but their composition is such that they almost certainly originated from rocks of the Wianamatta Group.

The dam was originally built in the 1880s, the completion year being quoted as 1888.

As originally designed, the dam's puddle clay core was nearly 9 m wide at the nominal design foundation level of the supporting shoulders at the dam's maximum section with 1 in 8 slopes up to its top, 1 m below dam crest level. The puddle clay core was extended some 9 m into the foundations. On either side of the core were transition zones between 7 m and 9 m wide in which selected clay fill from borrow areas downstream from the dam was placed and compacted in 150 mm layers. The flanking shoulders of the dam were also of clay fill from the same borrow

1 For the purposes of this report, left and right are deemed to be the left-hand and right-hand directions when looking downstream at the damsite.

PHOTOGRAPH I-1 - PROSPECT DAM - VIEW FROM LEFT ABUTMENT



PROSPECT DAM - VIEW FROM RIGHT ABUTMENT SHOWING SPILLWAY

PHOTOGRAPH I-2

areas, but in their case, the fill was placed and compacted in 300 m layers. Both outer slopes were effectively at 3 to 1. The upstream slope was protected by stone pitching on a crushed rock base. The downstream face was topsoiled and grassed. Details of this original design are given on the Board's drawing 341/23 (Figure I-2).

While the reservoir was being filled for the first time in 1888, a major slip occurred on the upstream face between the two dog-leg corners (see Photographs I-1 and I-2). A few months later during a rapid drawdown operation, the dog-leg corner closer to the maximum section suffered a slip on the upstream face. Remedial works in the form of dumped rockfill were carried out progressively over the next few years so that now the upstream face has a form of stabilising fill at the heel of the dam. At the maximum section, according to 1980 soundings, there is little additional fill but along the long right abutment portion of the dam, where the main slips occurred, the dam effectively has a 40 m wide and 3 m to 5 m high berm on its heel (see Figure I-3 which is the Board's drawing 1100/23).

Completing the dam section is the downstream stabilising fill, which was built in the late 1970s. The bulk fill material, which creates a net 6 to 1 slope below EL 57, is second-grade quarry material and waste sedimentary rock won from the nearby Prospect quarry. The stabilising fill is underlain by processed filter material and a drainage blanket. Within the foundations of the stabilising fill is a filter cut-off wall, up to 10 m deep at the dam's maximum section, and a series of vertical sand drains. This filter drainage system is connected by way of a pattern of collector drains to a toe drain for ultimate discharge downstream from the dam. The outer surface of the stabilising fill is grassed topsoil (see Photographs I-1 and I-2). Board's drawings 1084/23, 1087/23 and 1094/23 (Figures I-1, I-4 and I-5) give typical details of the stabilising fill.

The Board monitors seepage from the dam at a number of points within the stabilising fill system (discretely placed cut-off walls separate the fill into specific drainage areas). Periodically, chemical analyses of the seepage water are carried out. The Board also records pore pressures in the dam and the foundation with a number of Casagrande, hydraulic, vibrating wire and pneumatic piezometers. The piezometers are concentrated near and in the foundations. Surface movement points on the dam complete the monitoring devices.

The dam's free overfall spillway is at the right abutment of the dam (Photograph I-2). It comprises a small weir with a crest at the reservoir's full supply level (FSL) of EL 60.43 and unlined upstream and downstream channels. The control crest is 42 m long.

As will be discussed in the next section, upstream stability became an issue to all from April 1888 when a major upstream slip occurred between the two dog-leg corners during the first filling of the reservoir. The various points of the upstream stability and its associated remedial works are given in the next section. Enough to say here that rockfill was dumped into the reservoir at periods over the next 15 years to try to improve the marginal stability conditions of the upstream face.

With advances in soil mechanics, particularly in the understanding of the residual strength concept, the fact that much of the foundation could be at a very low strength set in train a major study in the 1960s. By the mid 1970s, the Board, which had taken over responsibility for Prospect in the early 1890s, decided that a downstream stabilising fill had to be built to raise stability of the downstream shoulder to acceptable levels. The construction of the downstream stabilising fill was done in the late 1970s.

At the same time as the investigations for the downstream stabilising fill were in train, the Board fully understood the implications of its findings on the upstream face. Simultaneously with the stabilising fill works, detailed site investigations and office studies began on the stability of the upstream side of the dam where the two major slips had occurred. The conclusions reached so far suggest that the stability of the upstream shoulder remains marginal at best but probably unacceptable for such a dam as Prospect.

3.2.2. Instability of the upstream shoulder

The intention in this section is not to give a definitive history of the dam's instability for such has been done far more authoritatively by the Board in many of its published and official documents (for example, the Board's 1986 surveillance report). The purpose of this section is to highlight the important points insofar as SMEC's assignment is concerned.

As noted in the previous section, failures occurred on the upstream face while the reservoir was being filled for the first time and soon after during drawdown. Almost certainly, there would have been signs of potential instability, even significant movement during construction, although such may have not been recognised by the builders at the time. In the case of the construction instability, the fact that the builders could not top out the whole of the embankment suggests that they found it virtually impossible to stop a slow slide from moving when they loaded its top. Later, in April 1988 as the reservoir was being filled for the first time the resulting decrease in

the resisting forces coupled with progressive gradual saturation of the foundations and possibly some of the compacted weathered material in the embankment upstream shoulder would have been the root cause of the major failure between the two dog-leg corners. Finally, in the drawdown operation a few months later, November 1888, not only would an excess pore pressure condition probably have been set up at and near the puddle clay core but also there would have been a marginal increase in driving forces at the expenses of the resisting forces, both of which would have been enough to swing the scales in favour of a slip. There is no doubt that the embankment, at least its upstream face, was then in a delicate balance between safety and failure.

After the initial trauma of the first of the major upstream failures in 1888, another minor slip also occurred near the maximum section in April 1888, dolerite rockfill was dumped into the water to form a stabilising beam at and alongside the failure zone. A similar operation followed the November 1888 failure, only this time rockfill was dumped on the upstream face along most of the length of the dam.

While much subsidence of the crest had accompanied the major slips, steady settlement continued throughout the late 1880s and early 1890s. Deformations of the puddle clay, were shown by sub-surface drilling to be appreciable, although by modern standards not alarming. As a result in 1893 or just afterwards a program of drainage works was begun on the downstream side of the core. The works included a number of tunnel drains at the dam/foundation interface and open vertical drains through the shoulder. The puddle clay core was also raised along its entire length in 1893.

In 1897 and again in 1899, there were further significant settlement movements at the dog-leg corner nearer the maximum section. Both were attributed to rapid drawdown of the reservoir.

Over the last few years of the century and into the start of the new century, a severe drought took place in eastern Australia. The drawdown of 1899 was probably a result of this drought but records of reservoir level suggest that not until 1901 and 1902 did the drought's full impact fall upon Prospect. By October 1902, the water had fallen by over 7 m below FSL. Severe longitudinal cracking along the crest had earlier been recorded and the Board, the then owners of the dam was in the process of fixing up the cracking. The report of the time strongly infer that a failure occurred at the first dog-leg corner when the reservoir was at its low point and the crest had been partially cut down. According to the 1902/1903 annual report, heel weighting proceeded steadily throughout this period at and near the dog-leg corner in October 1902 and presumably movements which occurred and were probably not that greater, were stopped quickly.

Even so, as the water levels fell again, this time in the first half of 1903, the bank failed at the dog-leg corner while works were been carried out on the crest to raise its design level. While the earlier drawdown of 1902 may have just initiated a slip, clearly the loading of the crest was the final straw, again showing just how delicately balanced the upstream stability was. But the events of 1902 did suggest that if the reservoir level could be taken down slowly enough, the records would say 0.15 m/week, then drawdown without major upstream slips elsewhere could be possible.

With the introduction of Cataract reservoir into Sydney's water system in 1911 and after many enquiries into Prospect's condition, a tentative limit of 1.8 m (6 ft) on drawdown was placed on the reservoir's operation. This stipulation became mandatory in 1925 and was tightened even further, to a 1 m drawdown limit, in 1980.

Other than the minor slips in the late 1930s and some crest subsidence in 1949, both events being coincident with reservoir drawdown, no slips have occurred since 1903.

4. GEOLOGY AND CONSTRUCTION MATERIALS

4.1. REGIONAL GEOLOGY

The Prospect reservoir is situated near the centre of the Sydney Basin close to the axis of the Penrith Syncline. The area is underlain by rocks of the Bringelly Shale, the upper sub-group in the Wianamatta Group of Triassic Age. This formation is composed of an interbedded sequence of siltstone, sandstone and laminate (a finely bedded sequence of sandstone and shale) with occasional bands of carbonaceous shale. The formation contains several repetitive sequences of these rock types. The regional structure is simple with a shallow dip to the north-west and occasional faults which involve small scale vertical displacements.

Immediately to the east of the embankment is the Prospect Intrusion - a large area of igneous rock which is currently quarried for aggregate. Several of the drill holes on the dam left abutment contain disturbed rock which may be related to the emplacement of the intrusion.[2] There is no record of dykes from the intrusion through the embankment area.

4.2. DAMSITE GEOLOGY

Except for roughly a 300 m length of the dam across the old creek bed, the dam is founded on residually weathered beds of the Bringelly Shale sub-group. Within the old creek bed area are the alluvial clays.

The 1977 investigation for construction of the downstream stabilising fill included the drilling of 60 holes (F1 to F60) by the Board. The logs of these holes confirmed that the subsurface profile consisted of interbedded sandstone and siltstone with a near surface layer of residual soil derived from these rocks along the whole length of the dam, including under the alluvial clays in the old creek bed. In 1980 the Board drilled 12 holes (PU1 to PU12) to investigate an area of the upstream slope at the dog-leg corner nearer the maximum section which had been affected by slope movement. These holes indicated a similar profile to the earlier holes but identified a zone

2 The intrusion must have caused much disturbance. There is shale on top of the intrusion. According to some, this shale is from the Ashfield sub-group of the Wianamatta Group which means it comes from over 50 m below the present damsite foundations.

of plastic clay beneath the embankment which was inferred to represent a possible "slide plane" for the slides of the late 1800s and early 1900s.

The recent drilling by the Board for the Prospect-Pipehead tunnel added further to the knowledge of the geology of the damsite. The exploratory drilling for this proposed tunnel, which begins just downstream of the embankment, included 14 holes (PPH1 to PPH14). They show a similar sequence of rock strata which appears to have a dip of about 2 degrees to the north-west and to be displaced by several faults with small vertical displacement.

On the left abutment, as already noted, the variability of measured dip in the 1977 exploratory holes in this area, suggests that the nearby dolerite intrusion has had a marked effect on the beds. Given the low strength of the present rocks, the intrusion was probably accompanied by local tearing, faulting and jostling rather than widespread drag. The fact that within distances as small as 30 m the bedding changed from 30° to virtually horizontal would confirm this assessment. Where the residually weathered rocks were exposed on this abutment, the apparent depth of complete weathering appears to be greater than on the other abutment, perhaps over 10 m deep.

Along the long right abutment, the foundation beds are more or less uniform, aside from probable offsetting by local faulting. The bedding is almost always recorded as nearly horizontal, which is consistent with the general geology of the area and is certainly consistent with the concept of the inferred "slide plane" at the dog-leg corner nearer the maximum section. The depth of complete weathering to essentially soils would seem to be about 5 m generally along the abutment. Where the Board was able to classify the material found in the drill holes as soil, invariably the soils fall into the classifications ranging from low plasticity clay (CL) to high plasticity clay (CH).

Within and on either side of the old creek bed, the alluvial clays were left in place during the construction of the dam. The Board has interpreted these alluvial clays as being in lenses of various classes of clays of up to 3 m thick with the total depth being roughly 7 m to 8 m maximum. They classify generally as low to high plasticity clays; in other words, they would behave similarly to the residually weathered soils on the abutments, although probably more variable from place to place than the weathered insitu clays.

Groundwater pore pressure and leakage measurements at the damsite coupled with the results of site investigations suggest two important conclusions can be drawn insofar as the foundations are concerned. Firstly, the permeability of the foundations, whether insitu or alluvial material,

when considered as a large mass is relatively low but not that low that seepage water cannot drain away from the dam. Secondly, the facts that seepage can get away and that the effectiveness of the puddle clay core would appear to be very good means that the groundwater surface on the downstream side of the core is essentially not far above the general level of the foundations. Certainly, for all intents and purposes, the water surface under the stabilising fill is literally coincident with the foundation level in the old creek bed area. On the right abutment, the piezometers, which are in the filter drainage blanket, simply prove that there is no water pressure in the blanket. The generally dry conditions found during the construction of the remedial works in the late 1970s suggest, perhaps, a groundwater surface below the foundation surface.

4.3. ENGINEERING GEOLOGICAL ASSESSMENT OF DAMSITE FOUNDATION

4.3.1. Review of available data

To assess the probable foundation conditions the information available from the 1977 and 1980 drilling for the section between Chainage 1100 m and Chainage 1500 m has been reviewed. The results of the review are shown on Figure I-6. The accuracy of the information is affected by the lack of data on location of the 1977 drill holes and the location and elevation of the 1980 drill holes. The location of the 1977 holes is based on drawing 1056/23 (Figure I-7) at a scale of 1:2000. Elevations for the 1980 holes has been based on assumed water surface of 59.4 m during drilling and a typical dam surface profile shown on drawing G71-40-1 (Figure I-8).

The drill holes show that the foundations contain a band of sandstone of significant thickness (more than 10 m) with interbedded siltstone and shale above and below this band. The sketch shows the elevation of the top and bottom (in brackets) of the sandstone band inferred from the logs.

The data indicate three zones with an apparent consistent dip to the north-west of about 1.5 degrees with the zones separated by a vertical displacement of between 2 m and 4 m. Possible fault lines have been included to give meaning to these displacements. This interpretation is in agreement with the geological structural features indicated by the tunnel investigation.

The upper boundary of the sandstone band beneath the upstream slope of the embankment in this area appears to be situated just below dam stripping level. A bank of siltstone/shale above

this interface dips at a low angle to the north-west and contains the plastic clay which may very well represent a zone of failure, perhaps one of several at that section.

4.3.2. Preliminary assessment

Based on the information available and allowing for the inaccuracy of location and elevation data, the presence of a shallow dipping band of low strength shale/clay beneath the upstream slope of the embankment may have contributed to the failures which have occurred on the right abutment. Given the nature of the clay and that significant movement has probably occurred within it, the material is probably at or very close to its residual strength (see later in this report for discussion on residual strength). The importance of the upstream dip albeit a very small dip, is that it would in effect be equivalent to a direct reduction in the residual strength value of the same amount.

Taking the broader view and extending this assessment over the length of the dam where it is founded on residually weathered material, the apparent upstream dip on the beds would put the whole of the upstream shoulder on right abutment at marginally greater risk than the downstream shoulder. In coming to this conclusion, the assumption has been made that a very likely failure surface would be along but just above the top of the sandstone layer. Perhaps, the postulated faulting could be interpreted as the reason for the major upstream failures being confirmed to two areas. Such may be the optimistic approach; the more cautious and responsible approach would suggest that without proving absolutely that weak material does not exist in any other chosen areas, a potential weakness must be assumed over the whole of the right abutment foundations of the original dam at or just below the excavated surface. Further, because considerable movements over time may have occurred at the interface, the strength assigned to this material should be at or close to residual.

On the left abutment, above the alluvial materials, the possible disturbed nature of the bedding due to the dolerite intrusion could be construed as eliminating this part of the abutment from the risk of potential foundation failure. The Board's interpretation of the drill cores here would again dictate much care and caution be exercised. The depth of material which can be classified as a clay soil is more here than elsewhere. Thus, again the risk of a low shear strength material being present cannot be ignored.

The same argument would apply to the alluvial materials in the old creek bed. More will be said about them later in the next sections of this report. What can be said is that their engineering

properties are not dissimilar from the residually weathered soils. If anything, their residual strengths are marginally higher but the number of test results are too limited to be definitive about such an assessment. Again, caution would favour accepting similar potential weak zones at or just under the dam/foundation interface.

Aside from lack of enough factual data extending over the full area of the upstream foundations in particular, the tendency towards a conservative approach can be argued from the point of view of what was the condition of the exposed foundation. Only relatively vague reports from diaries are apparently available so assuming that the builders carried out minimal stripping is the only choice to be made. The foundations of the flanking shoulders must therefore be taken to be in very weak residually weathered rock or weak alluvial clays.

The presence of a low water table, as has been recorded in the downstream slope, may be partly due to the presence of sandstone immediately below the embankment in this area which provides some drainage through joints towards Prospect Creek.

4.4. CONSTRUCTION MATERIALS

4.4.1. Original dam

Of the two main construction materials, namely the earthfill in the flanking shoulders and the clay in the puddle clay core, the major concern with the dam's stability is with the compacted fill in the shoulders.

The source of the clay in the puddle core is not known to SMEC. But its performance in the dam over the years indicates that it is well suited to the job it has to do. As may be expected, the puddle clay consists of high and intermediate plastic clay with generally a high liquid limit. Certainly, when allowed to dry out, the puddle clay does crack. The object has been and will be in the future to keep the moisture content high enough to stop these cracks near the top of the core from developing.

The compacted fill in the dam's shoulders came from a borrow area in the residually weathered clays downstream from the dam. The method of working the borrow areas by steam-powered shovel digging up a reasonably high vertical face would have mixed up the individual loads. Once placed and compacted on the dam the fill would be certainly more variable in grain size from layer

to layer and within any one layer than the uniform beds in the foundation. Even so, the classification tests over the years have shown that the bulk of the fill is a mixture of low to high plasticity clays.

That the fill's compaction would be acceptable by modern day practices is doubtful. Indications are that some of the fill is no more than 95% of its maximum dry density and data from tests in 1967 by the former Water Conservation and Irrigation Commission points to variation of density through layers. Such variability would be expected when compacting in 300 mm layers. Thus, low density material could be expected over quite large areas of any one layer.

Given the variability of the material in the bank, even allowing for doubts on its compaction, failures, if they were to occur, would most likely be preferentially in and along the more uniform weak clay layers at and near the foundation interface rather than along layers of the dam fill. Even so, without a full program of testing there would always be some doubt and the safest course would be to assume that the fill was only slightly better than the saturated foundation clays, particularly as there may have been extensive areas of soft, low density clays at the bottom of some layers. Conservatively, residual strength or close to it would be appropriate parallel to the layers for a final design but such an assumption would belie the fact that the dam is not in a state of failure now.

The existence of apparent perched water tables in the downstream shoulder confirms the variable nature of the fill, particularly the probable presence of more sandy material overlain and underlain by impermeable clay layers.

A final comment on the shoulder fill is warranted. An almost cursory look at the grading and classification data from the 1967 and the 1980 testing would suggest that there is more sandy clay fill in the downstream shoulder than on the upstream side of the dam. Such would be consistent with the behaviour of the pore pressures measured in the downstream shoulder. Maybe, it is another reason, albeit in a minor way, for the fact that failures occurred on the upstream side.

4.4.2. Upstream stabilising fill

The almost uncontrolled dumping of dolerite fill through water onto the dam's heel at best can be accepted as low density clay fill. Without some means of stopping the boulders sinking into the foundations, the fill must be viewed simply as a poor extension of the dam clay shoulder.

4.4.3. Downstream stabilising fill

All available data confirm that the design and construction of the downstream fill, including the testing and selection of the construction materials, meet the high standard demanded of modern day dam embankments. The materials, from the second-grade quarry run fill for the main fill to the graded gravel filters to the sand in the sand drains, have been proved to be more than adequate for the stabilising fill.

4.5. SEISMICITY AND RELATED FACTORS

4.5.1. Seismicity

At the time (19 September 1991) of the first issuing of this report, SMEC had only made verbal contact with Mr Gary Gibson of the Seismology Research Centre at the Phillip Institute of Technology. His preliminary assessment of the peak ground acceleration for the 1 in 10 000 annual exceedance probability (AEP) event[3] was 0.3 g. It was later increased marginally to 0.33 g.

If the 1 in 10 000 AEP event is accepted as a reasonable measure of the maximum design earthquake event, then simple pseudo-static analyses will probably be reasonable in assessing the dam's ability to withstand ground shaking. The seismic coefficient for such analyses would be somewhere between 0.1 g and 0.15 g based on the work of Marcuson and Franklin (Reference I-2) and Jansen (Reference I-3). A later paper by Franklin and Hynes-Griffin (Reference I-4) proposed a seismic coefficient of one-half the peak ground acceleration of the base motion.

In accepting that a simple pseudo-static analysis is enough or even if a full dynamic study were needed, there is the over-riding assumption that no active fault exists under the dam. All indications from the Board's own investigations and SMEC's assessments elsewhere in Australia would suggest that such an approach is correct.

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[3] Quoting the 1 in 10 000 AEP event as the design event is to accept that it is equivalent to the selection of the 1 in 10 000 AEP flood as the recommended design flood (RDF). The ANCOLD guidelines (Reference I-1) propose a range of the 1 in 10 000 AEP flood to the PMF as the RDF for a high hazard dam. May be the 1 in 10 000 AEP earthquake is not severe enough for such an important high hazard dam as Prospect.

4.5.2. Liquefaction potential

Given that all of the material in the foundations and in the original dam is clay would seem to preclude the risk of liquefaction. Likewise, in the downstream stabilising fill, all except the sand blanket filter (designated Zone 2B on Figure I-1) would not be prone to liquefaction.

The Zone 2B filter underlies the whole of the downstream stabilising fill. It is a sand but its design grading was quite wide, particularly at the maximum particle size end. It was also deliberately compacted "in the dry" but only to a minimum specified density of 60% relative density.

Assuming that across the old creek bed the filter blanket is partly submerged and that it is on the fine side of the design grading, then for a 60% relative density and a peak ground acceleration 0.3 g, the filter would have the potential to liquefy (Reference I-5). In favour of such not happening is that the sand filter is not a uniform sand and is not fully submerged. Further, the 1 in 10 000 AEP earthquake is probably going to be less than a magnitude 7 event so that the number of cycles the sand would be subjected to would be less than under the action of more severe events upon which the design curves in Reference I-5 were probably based. It takes a certain number of loading cycles to start the liquefaction.

Data from the Board's construction records shows that river sand was used between Chainage 130 and 350, that is, up the left abutment of the dam to a section just to the left of the maximum section. This sand was reasonably well graded but a "first test" average relative density of only 64% was achieved with a range of 50% to 90% The in-place average is probably closer to 70% as all material below 60% relative density was presumably re-rolled. The other source of sand was Cronulla sand (dune sand), a more uniformly graded sand. With no indication to the contrary, this sand was presumably used over the rest of the foundation, including the maximum section. Its "first test" average over a range of 55% to 95% relative density was 75%. Again the final average value would have been higher with re-rolling. Accepting that the averaging relative density in place over the maximum section is 75%, then, all things considered, the risk of this partly submerged sand liquefying is probably almost zero.

Nevertheless, there is some lingering doubt about the Zone 2B filter within the old creek bed. Elsewhere, the groundwater surface is probably below the foundation surface of the stabilising fill so that liquefaction will not enter into the equation.

4. UPSTREAM STABILITY AT FIRST DOG-LEG

4.1. PERFORMANCE HISTORY

Prospect dam embankment, when viewed in plan, has two dog-leg corners, one at about Chainage 1332 and the other at about Chainage 1793. The corner closer to the maximum section of the dam, referred to in this report as the first dog-leg, has had a history of instability in its upstream shoulder.

The reservoir was first filled during the first half of 1888. Failure of the upstream slope at the first dog-leg was first reported in November 1888 when the reservoir was being drawn down and its level was at about RL 55.0. Inspection of the upstream toe of the embankment by a diver indicated that the slip surface exited the slope just upstream of the stone dyke which retained the toe of the slope. At least some, and probably a major portion, of the slip surface was within the foundation. Rock was dumped through water on the upstream toe of the embankment to stabilise the slope.

In April 1897 a settlement again developed while the reservoir was drawn down to RL 56.87 m. No accompanying movements were reported but such may have occurred below water level and gone unnoticed.

A further subsidence accompanied by horizontal movement took place in February 1899 with the water level at RL 58.09 m. Slope movements were stopped by placing more rock on the upstream toe of the embankment.

Although not clearly stated in the engineer's annual reports of the time, some significant movements seemed to have occurred in October 1902 when, in a severe drought, the reservoir reached its lowest level since the initial filling of 1888. Work on repairing and replacing the puddle clay core in and near the dog-leg had been underway for some time. When the movements took place in October 1902, the crest had been partially cut down. Some months later, on 15 May 1903, further slope movements occurred with the reservoir at about RL 55.2 m. The reservoir had gone up after the low point of October 1902, but had fallen again. Replacement of the crest was nearing completion when the slip happened.

The total movements in the upstream shoulder during the period 1888-1903 were probably of the order of several metres and suggest that almost all of the slip surface on which movements occurred in 1902-3 was at residual strength. Skempton (Reference II-3) quotes movements in the range 100 mm to 500 mm as typical values required to reach residual strength.

4.2. BACK-ANALYSES OF 1902-3 SLIDES

4.2.1. General

Back-analyses of the upstream slope at Chainage 1344, near the first dog-leg were carried out. An analysis was done for the conditions which existed on 15 October 1902 and a second analysis relates for the conditions which existed on 15 May 1903. In both cases, given that this dam did suffer failure at the first dog-leg corner, the assigning of an FOS of one to the assumed failure surface cannot be disputed.

It was assumed that the uppermost layer in the foundation is a residually weathered clay which has an apparent dip in the upstream direction of 1.5°.

When performing back-analyses the geometry, pore pressures or material strengths or any combination of these conditions and parameters are varied until the FOS on the critical failure surface, or the actual slide surface if this surface is known, reaches unity.

For Chainage 1344 the geometry and pore pressures were considered to be known and the material strengths were varied. The existence of the dog-leg will marginally reduce the amount of side restraint provided to the slide, but this effect is difficult to quantify and has not been incorporated into the analysis.

In both analyses pore pressures were everywhere set at hydrostatic to the reservoir level. This condition assumes that excess pore pressures generated in the foundation during construction of the original embankment and during later dumping of stabilising rockfill had completely dissipated. It also assumes that the excess pore pressures in the core and upstream shoulder resulting from construction and subsequent drawdown had also completely dissipated.

By adopting these lower bound pore pressures, lower bound back-calculated strengths follow. Often the tendency is to accept that the worst possible pore pressure regime applies and the

5. UPSTREAM STABILITY AT CHAINAGE 1768

5.1. PERFORMANCE HISTORY

The Chainage 1768 section, referred to in the early days as TS 54, is located between the first and second dog-legs. On 22 April 1888, during initial filling, instability was observed at this location when the reservoir level was at about RL 55.93. Horizontal movements of up to seven metres were measured on the upstream face. Borings through the upstream shoulder indicated that the stone dyke retaining the toe of the embankment was still in its original position and that movements appeared to be taking place on a slip surface with a basal failure plane about 2 to 2.5 metres above stripped ground level.

It was postulated at the time that the failure could be attributed to the nature of the material which had been used in the shoulder at that elevation. It had included a significant amount of material which had previously been rejected as puddle core material.

Evidence given at a Royal Commission suggested that at and on either side of this section, construction had been delayed somewhat foundation problems within the core trench and that the construction on either side was well advanced when the reject puddle clay was placed in the shoulders. The indications are that tendency throughout the construction was to place the more clayey material in the upstream shoulder so that a reasonable conclusion would be that much of the reject core material went into the upstream shoulder at the Chainage 1768 section.

5.2. BACK-ANALYSIS OF 1888 SLIDE

5.2.1. Input data

A back-analysis of the embankment at Chainage 1768 has been carried out. The section used in the analysis is shown in Figure II-6.

Pore pressures hydrostatic with reservoir level were assigned to the slope. The core was notionally extended downstream and assigned a strength equal to the residual of 12° as derived in Section 3.3.

Slip surfaces were constrained to a failure plane about 2 to 2.5 m above foundation level. The embankment shoulders had been constructed in layers with a slope towards the core of 1 in 12 (about 5°) and the basal failure plane in the analysis was assigned a 5° dip in the downstream direction (see Reference II-1 for comments on the probable weaknesses of the shoulders being concentrated within the layers rather across the layers.)

The strength of the shoulder material was varied to assess its influence on the stability of the slope

5.2.2. Results

The slip surface shown on Figure II-7 gave a FOS of 1.19 for a friction angle of 12° in the upstream shoulder. This FOS came from a pore pressure distribution which probably erred on the low side. If any excess pore pressures were included the FOS would quickly drop towards unity, the value the FOS must have been when the failure occurred in April 1888.

The analysis suggests that, at its worst, the residual strength of the upstream shoulder is not significantly greater than that of the core and the weakest layer in the upstream foundation.

6. ASSESSMENT OF UPSTREAM STABILITY

6.1. PERFORMANCE HISTORY

Apart from the failures discussed in Section 5, no others have been reported in the upstream shoulder or foundation.

Settlements of the core at Chainage 610 (TS 20) were reported on 3 June 1888, but these movements do not appear to have led to a fully developed slip surface passing through the upstream shoulder or its foundation.

The upstream shoulder of the embankment at Chainage 432 (approximately maximum section) does not appear to have deformed significantly since construction. Based on soundings taken in 1980, the stone dyke retaining the toe of the upstream slope still appeared to be in its original position.

6.2. KNOWN BEHAVIOUR OF CLAYFILL DAMS ON CLAY FOUNDATIONS

SMEC has recently carried out a finite difference analysis of the behaviour during construction of a zoned earthfill dam on a low strength foundation. The dam had a cross section similar to that of Prospect. The analysis showed that a significant zone of failed material developed in the core while the minimum FOS (by limit equilibrium methods) on the critical slip surface was still in excess of 1.2. The strength of the failed core material dropped rapidly from its peak value to a fully softened or critical state strength. Thereafter strength loss proceeded more slowly as the material moved towards its residual strength. The zone of failed material was initially confined to the core but as construction proceeded towards topping out and the FOS dropped below 1.2, the failed zone extended out of the core and into the upstream shoulder. The failed zone continued to extend upstream as construction proceeded until it formed a continuous zone of failed material passing through the upstream shoulder when the FOS had dropped to about one.

It is believed a similar pattern of material failure and strength loss could have occurred in Prospect if the slope had been approaching a FOS of one. In order to assess the stability of the upstream shoulder it is necessary to know the distribution of available shear strength within the embankment and its foundation.

SMH 2-4-1992

Sydney dam to be made quake-proof

By COL ALLISON

The 25-metre-tall wall of Prospect Reservoir, Sydney's oldest dam, built in 1888, is to be reinforced to prevent it collapsing in a severe earthquake.

In the meantime, the Water Board is lowering the water level by almost a metre so the $10 million remedial construction work can begin as soon as possible on the part of the two-kilometre-long wall most vulnerable to earthquakes.

The managing director of the Water Board, Mr Bob Wilson, said yesterday that strengthening was necessary following the introduction of new dam safety specifications drafted in the wake of the Tennant Creek earthquake in January 1988 and the severe quake which shook Newcastle in December 1989.

"We are not taking any risks and would prefer to err on the side of caution," he said.

The wall holds back 50,000 megalitres of water from Warragamba Dam and is critical for Sydney residents. It is the settling pond and distribution outlet for 80 per cent of the metropolitan water supply.

If it failed, not only would the city of Fairfield, 50 metres closer to sea level, be engulfed, but Sydney would be virtually without water.

"You could shut the place up then and if you wanted a drink you'd have to drive to Warragamba with a bucket," a long-time anti-dam lobbyist and executive of the Fairfield-based Citizens' Action Movement, Mr Bob Young, told the *Herald*.

Mr Young described Prospect Reservoir as: "The most dangerous dam in NSW. If it burst the loss of life would be horrific."

He has written to Fairfield City Council urging aldermen to press the Water Board for more safety measures.

Mr Wilson said the board was checking all its dams against the new earthquake design loadings.

E6

PROSPECT (Town or District)	SYDNEY WATER SUPPLY PROSPECT RESERVOIR Prospect Dam (Name or Identification of Listing)	C.M.A. 1:25,000 series Prospect Sheet, 9030-11-N 050/545 U.B.D. 21st Edition Maps 59c & 60 (Address or Location)
Post Code 2149 City of Local Govt Area Blacktown		
Author of Proposal J M Collocott		
Date of Proposal July 1985		
Suggested Listing Category CLASSIFIED	Bibliography 1. The Water Supply, Sewerage & Drainage of Sydney-W V Aird, Halstead Press 1961; 2. Metropolitan Board of Water Supply & Sewerage-Official Hand-Book, 1913; 3. M.W.S. & D.B. archives	Owner and Address Metropolitan Water Seweraga & Drainage Board Cnr Pitt & Bathurst Sts SYDNEY NSW 2000
Committee (Trust Use) IAC		
Council (Trust Use) APPROVED 23/9/85		

Description — Briefly cover the points on the following check list where they are relevant and within your knowledge.

Style / Construction / Use / Architect/s / Builder/s / Date of Construction / Present Condition / History / Owners / Boundaries of proposed listing

DESCRIPTION: 1.

1.1 Prospect Reservoir is Sydney's largest service reservoir and stores water conveyed from Warragamba Dam, the Upper Nepean Dams (Cataract, Cordeaux, Avon and Nepean) and, if need be, the Shoalhaven Scheme, for supplying the larger componen of the water distribution system of the Sydney metropolis. It is located 30 kms west of Sydney, has a total storage capacity of 50,000 megalitres and an operatin capacity of 8,870 megalitres.

1.2 Prospect is an earth dam 2,210 metres long consisting essentially of a puddle clay core with shoulders of selected earth placed in layers 300 mm thick compacte by rolling. It was completed in 1888, but in 1898 the crest level was raised by approximately 0.5 m to give a profile as shown in the attached sketch titled Prospect Dam, Typical Cross Section. The upstream slope of the wall is pitched with locally quarried diorite blocks 450 mm thick.

1.3 Remedial works, to correct slumps in the upstream face were carried out in 1893, 189 1899 and 1902, whilst in 1980 the Board completed a major strengthening of the dam by greatly increasing the volume of the downstream side of the wall and providing improved drainage facilities in the light of modern knowledge of the stability of earth dams. This did not alter the length or height of the wall, or the top water level, but only the volume and slope of the downstream side. (See attached sheet

Reasons for listing

See attached sheet (page 5)

Sketch plan and photos
Attach additional photos if any.

1.4 The description of Prospect Reservoir as given in the Official Handbook of 1913 is as follows:-

Catchment area above embankment	2,400 acres (972 ha)
Area of water surface when full	1,266 acres (513 ha)
Total contents 196.67 contour (60m)	11,029 million gallons (50,182 MI)
Total contents 177.50 contour (54m)	5,527 million gallons (25,148 MI)
Quantity available by gravitation	5,502 million gallons (25,034 MI)
Pumping limit 131.00 (40m), 80,74 acres (32.7 ha)	93 million gallons (423 MI)
Amount available by pumping after gravitation limit has been reached	5,434 million gallons (24,725 MI)
Total quantity available by both pumping and gravitation	10,936 million gallons (49,759 MI)
Length of dam (earthenwith puddle core)	7,300 feet (2,225 m)
Maximum height of dam	85.67 feet (26.1 m)
Slope of dam - 3 to 1 on water side	
Slope of dam - 2½ to 1 on outer side, with two 15 feet (4.6 m) berms	
Width of dam at top	30 feet (9.1M
Length of side spillway weir	141 ft. 2½ ins (43m)

Owner and LGA notified, Form letter IAC/2a 9/10/85

2.

2.1 Prospect Dam was built as a major component of what is known as the Upper Nepean Scheme which was Sydney's fourth water supply source.

The essential feature of that scheme was, and still is, the diversion of the flow of the Nepean River (below its junctions with the Avon and Cordeaux Rivers) by a weir at a point on the Nepean known as Pheasants Nest, near the township of Wilton, through a 7 km long tunnel to the Cataract River at Broughtons Pass, near the township of Appin, where a similar weir on that river diverts the combined flow of the four rivers through a 58 km system of tunnels, aqueducts and open channels to Prospect Creek on which the Prospect Dam earthen wall was built.

2.2 When completed in 1888, the Upper Nepean Scheme depended for water entirely on "the run of the rivers", because virtually no storage is provided by the Pheasants Nest and Broughtons Pass Weirs, so Prospect Reservoir provided the <u>storage</u> component of the scheme to tide over periods of low river flow.

2.3 Since then, major storage dams have been built on the Upper Nepean Catchment Rivers (Cataract, Cordeaux, Avon and Nepean) and on the Warragamba River (which dam has a capacity of over four times the combined capacity of all of the Upper Nepean Dams) resulting in Prospect's role being changed to that of a major <u>service</u> reservoir to cover daily fluctuations of demand in the distribution system.

2.4 It might be noted that Prospect Reservoir has a total catchment area of only twice the area of the stored water, i.e. the lake area plus the same area of land. Therefore it receives practically no run-off and depends almost entirely on water conveyed to it by the Upper Canal and Warragamba Pipelines.

3.

3.1 Today, Prospect Reservoir is the scene of a fascinating combination of the "old and the new".

In conjunction with the Upper Canal, which feeds water in, and the Lower Canal, which feeds water out, both of which also are original components

of the Upper Nepean Scheme, it continues to operate as planned by the creators of that scheme in 1880.

But it has also fitted in with major amplifications of the water supply system to meet Sydney's ever growing needs, and on its shores are now located modern electric pumping stations which deliver water to as far away as Thorleigh high up in the North Shore, whilst major steel pipelines also take water from it by gravity, and, on its western side, it receives the discharge of Warragamba Dam through two very large steel pipelines, 3 metres and 2.1 metres in diameter respectively, controlled by modern "push button" needle valves.

3.2 Some origianl stone and sandstock brick structures still house valves and other hand operated control equipment some of which date back to the construction of the dam in the 1880's.

4. Not far from the north eastern shore of the lake may be found the remains of "Veteran Hall" the historic homestead of William Lawson who accompanied Blaxland and Wentworth on their famous first crossing of the Blue Mountains in 1813. These relics have been fenced off and marked with a memorial cairn erected by a small group of Sydney Water Board engineers.

5. The Water Board has provided most attractive picnic areas at Prospect with gardens, toilets, barbecues, firewood and hot water, together with a high level lookout area with panoramic views of the reservoir and surrounding country - all of which contribute to make it a particularly popular recreation area for the general public.

6. The boundary and curtilage of the classification is defined by the following summary:-

The boundary of grounds owned or controlled by the Metropolitan Water Sewerage and Drainage Board including the reservoir itself and the reservoir earthen wall and ancillary structures:

- The side spillway weir and channel at the southern end of the wall.

- The drainage and monitoring installations at the toe of the downstream face of the wall.

- The access road along the toe of the downstream face of the wall.

- The outlet works connecting the stored water to the Lower Canal - consisting of outlet tower, pipelines, valve house and valves, scour lines and valves, and other screening, metering and control installations.

REASONS FOR LISTING

1. The historical significance of Prospect Reservoir as an essential component of Sydney's 4th Water Supply which scheme was the result of the first major engineering investigation into the ongoing water supply needs of the rapidly growing city.

2. The engineering significance of Prospect Reservoir as being the first large storage reservoir to be built for Sydney's water supply, the design and construction methods used being the most advanced for that era.

3. The ongoing role of Prospect Reservoir as the Upper Nepean Scheme was progressively developed by the construction of major storage dams on the Cataract, Cordeaux, Avon and Nepean Rivers, and, later, with the construction of Warragamba Dam which alone quadrupled the total storage of all four Upper Nepean dams combined.

4. Its continuing role as a major service reservoir.

E7

Centenary of memories

Blacktown City Star, Wednesday, October 5, 1988

A PROUD Bill Pincott shows off the earth roller brought from Ballarat by his father to help build the Prospect reservoir.

At 94 years, Bill Pincott of Kings Langley is the oldest living former employee of the Water Board, which this year celebrates its centenary.

Old Prospect remembered

Although he only worked for six months with the Board, together with his father and three brothers they notched up 100 years service.

Bill still gets a little sentimental when he goes back to his birthplace on the banks of Prospect Reservoir.

"It's home, I love the place," he said.

In 1883 Bill's father George brought the massive volcanic stone roller used to compact the dam walls to Prospect from Ballarat by horse drawn wagon.

About 1500 men and their families lived in a makeshift camp overlooking the construction site.

The Pincott family was raised in one of the still standing cottages at Prospect.

After bringing the roller, George Pincott stayed on to take charge of a team of 100 horses and drays carting gravel for the dam walls.

Bill vividly recalls those early construction days at Prospect when the paymaster travelled from Parramatta in an unguarded sulky and then by horseback — accompanied by his George's father — to workers elsewhere in the bush.

His father was also chief of the stables built by William Lawson of Blue Mountains crossing fame, and whose grave is at Prospect.

Bill worked for the Water Board in 1928 as a fitter and turner.

He recalls with some delight being lowered as an eight-year-old inside a boiler because none of the maintenance men was small enough to do the cleaning work.

After returning from four years active duty in France in World War 1, during which he was wounded three times, Bill worked as a fitter and turner at Potts Hill, Bankstown, but eventually joined the colliery industry to become an electrical engineer.

Bill was married to his wife Doris for 50 years. She died in 1974.

He says the secret of his longevity is the exercise he got during his youth.

"I used to walk three miles from Prospect to Toongabbie station, to catch a train to Parramatta to go to school," Bill said.

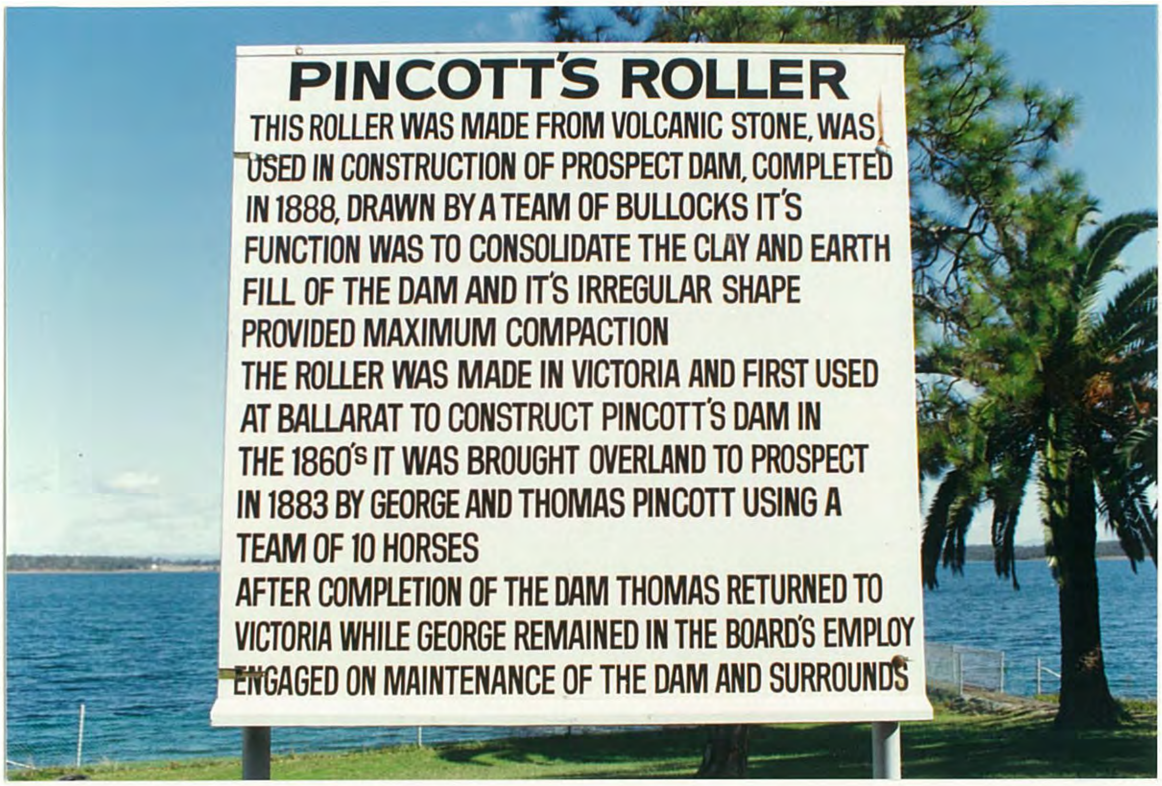
"I don't drink or smoke. However during the war I smoked and drank rum."

Bill still takes a half hour walk every day (weather permitting).

He celebrated his 94th birthday during his three-day stay at Expo recently.

Recently Bill was presented with the book Sweat of Their Brows by NSW Environment Minister Tim Moore and university researcher Margo Beasley, who wrote the book.

A contemporary photograph of Prospect Dam nearing completion in early 1888. Despite some blur, it is possible to distinguish a bullock team on the embankment pulling the roller.


PINCOTT'S ROLLER
THIS ROLLER WAS MADE FROM VOLCANIC STONE, WAS
USED IN CONSTRUCTION OF PROSPECT DAM, COMPLETED
IN 1888, DRAWN BY A TEAM OF BULLOCKS IT'S
FUNCTION WAS TO CONSOLIDATE THE CLAY AND EARTH
FILL OF THE DAM AND IT'S IRREGULAR SHAPE
PROVIDED MAXIMUM COMPACTION
THE ROLLER WAS MADE IN VICTORIA AND FIRST USED
AT BALLARAT TO CONSTRUCT PINCOTT'S DAM IN
THE 1860'S IT WAS BROUGHT OVERLAND TO PROSPECT
IN 1883 BY GEORGE AND THOMAS PINCOTT USING A
TEAM OF 10 HORSES
AFTER COMPLETION OF THE DAM THOMAS RETURNED TO
VICTORIA WHILE GEORGE REMAINED IN THE BOARD'S EMPLOY
ENGAGED ON MAINTENANCE OF THE DAM AND SURROUNDS


PINCOTT'S ROLLER

THE ADVERTISER, Wed., June 17, 1981

Old dam roller wrangle grinds to a full stop

THE wording on a sign above a century-old stone roller on display at Prospect Reservoir has been changed at the request of an 87-year-old Ermington man.

Mr Bill Pincott, of Marsden Rd, West Ryde, wanted the wording changed to recognise his father, George Pincott, and his uncle Thomas, who brought the volcanic stone roller to Prospect in 1883.

The sign now names the roller "Pincott's Roller" and tells how Mr Pincott and his brother brought it to Prospect and used it during the construction of the dam.

On the old sign Mr Pincott was not mentioned.

The sign told of the 10 horses who dragged it to Prospect from Ballarat, but didn't say who drove the horses.

At least once a month Bill Pincott returns to the reservoir with his sister, Hilda, to picnic and recall childhood memories.

"It's home, I love the place," he said last week.

MR Bill Pincott with the century-old stone roller and the new sign giving credit to his father and uncle for bringing it to Prospect Reservoir.

The historic roller was originally used to construct Pincott's Reservoir, near Ballarat.

The Victorian dam was named after Bill's grandfather, who was a commissioner responsible for the project.

After bringing the roller to Prospect, George Pincott stayed on to take charge of a team of 100 horses and drays used to cart gravel for the wall of the dam.

Close to 1500 men and their families lived in a makeshift camp overlooking the construction site, which was administered by the Public Works Department until the Water Board came into being in 1888.

Throughout his school days Bill lived with his parents and 10 brothers and sisters in a cottage which is still standing near the reservoir's pumping station.

After returning from active duty in World War II, Bill worked for the Water Board as a fitter and turner at Potts Hill.

However, he left after only a few months to join the coal mining industry in Lithgow as an electrical engineer.

Bill was researching his family history when he decided to contact the board about the sign above the roller.

He was put in touch with the board's archives officer, Mr Noel Thorpe, and the two worked on preparing a detailed history of the roller.

Mr Thorpe then prepared the wording for the new sign, which was installed a few weeks ago.

On a recent call at Prospect Reservoir, the stone roller attracted the attention of a visiting Engineer accompanying me. After commenting very favourably on the exhibit, he expressed the thought that it might become subject to weathering in due course, and wondered if a protective canopy might be of assistance.

L. Montagu.

Public Relations Officer.
3. 2.60

Chief Maintenance Engineer. 4/2/60

4 FEB

Referred for your consideration

8 FEB 1960

for CHIEF MAINTENANCE ENGR.
4 FEB 1960

RES. ENGINEER HEADWORKS 5 FEB 1960

It is felt that as the roller has been out in the weather during and since construction of Prospect Reservoir in 1886 and the weathering of stone is negligible, a canopy is not yet necessary.

Inspection will be made intermittently to detect any deterioration, when a cover will be provided.

A/Resident Engineer,
Headworks.
10.2.60.

Chief Maintenance Engineer.

10 FEB 1960

I agree.

for CHIEF MAINTENANCE ENGR.
10 FEB 1960

Public Relations Office.

11 FEB 1960

Public Relations Officer 11 FEB 1960

Received A.M.
11 FEB 1960
CENTRAL RECORDS

Noted

L. Montagu.
17/2/60.

FEB 1960

ADDENDUM TO 8 / ~~H~~ 9/71

It was intended to place a copy of the Jou[rnal] article giving full details of the history of the sub[ject] roller on this file, before making any submissi[on on] its disposal. However the Public Relation Offic[er ...] that due to lack of space the article on this roller [to be] deferred to the April 1958 issue.

Mr Rawlings suggests that rather than offer [the] roller to the Museum of Applied Arts and Sciences a[s] it might be retained and placed in a suitable position [...] to, or in the new picnic area which is being deve[loped] in this location.

It is contended that this roller was the [forerunner] of the present day mechanical sheep's foot roller.

D. Cumming
Clerk Class II.

ADDENDUM TO 8/1712-9

HEADWORKS

Old Stone Roller At Prospect Reservoir

Please refer to my minutes of I8.7.57 and 2.I0.57

Not having received any instructions on disposal of ol it has now been moved to near the main wall - and placed in a enclosure.

A notice board 3'0"xI'6" giving the following informat being painted and will be placed on roller -

" M. W. S. & D. B.
PROSPECT RESERVOIR

This roller is made from volcanic stone found in Victoria. It was first used at Ballarat Victoria before being brought to Prospect in I880 for use in the consolidation of the earth wall.

It was drawn by a team of ten horses and its irregular circumference afforded maximum consolidation. "

Forwarded for your information.

Chief Maintenance Engineer.

[signature]
Resident Engineer,
Headworks.
I0.2.59

Journal article "Prospect Reservoir" published April 1958 is attached for information. As an item of historical value and tourist visitor attraction, it is considered that Mr Hills action in placing the roller where it is now located is a good solution as for the disposal of this sheep's foot roller, and no action should be taken to pass it on to any Museum. Papers might be registered and filed for historical purposes.

D Cummins
CLERK CLASS I
26 JAN 1960

Records R.M.

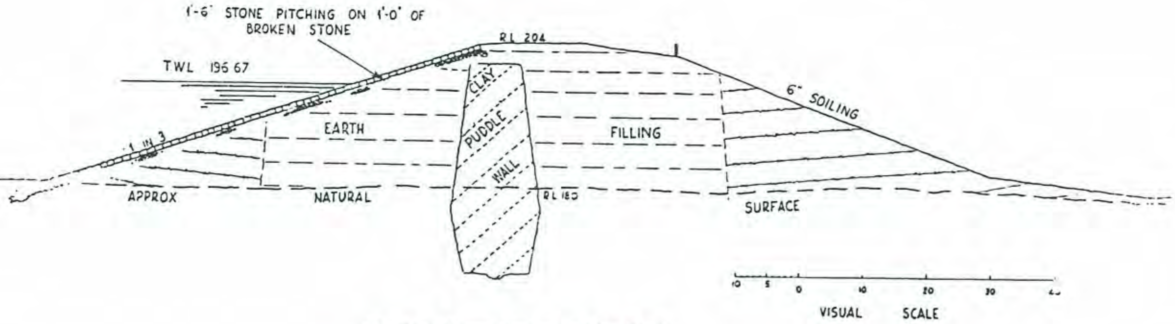
Prospect Reservoir

The bringing under notice recently of the fact that in an old quarry at Prospect there is preserved a stone roller of the type used on civil engineering works in bygone days conjures up memories of the construction of Prospect Reservoir over seventy years ago. This Reservoir and its surroundings form an interesting link with the early history of New South Wales, the larger portion of the 2,000 acres resumed for it, together with the historic residence known as " Veteran Hall," having been formerly held by William Lawson. From this homestead Lawson departed to meet Messrs. Blaxland and Wentworth at the former's farm at South Creek, whence they started on their memorable journey across the Blue Mountains; and there, after he resigned his military appointment, he spent the evening of his life until his death in June, 1850. The house was the residence and local office of the Board's Engineer in charge of the Head Works from 1888 to 1912, after which it and the surrounding paddocks were leased until 1915 to the Commonwealth military authorities for a remount depot. Subsequently, it was offered to the Commonwealth Government as a home for returned invalid soldiers, but this being declined, it was demolished in 1929.

At the inception of the Upper Nepean Scheme in 1888 Prospect Reservoir provided the only storage for Sydney, being fed by the Upper Canal from the flow of the Cataract, Cordeaux, Avon and Nepean Rivers. With the completion years later of the large storage dams on these rivers, the function of Prospect has changed from that of a storage reservoir to that of the main service reservoir and sedimentation basin of the metropolitan system.

When first completed the reservoir had a storage capacity of 10,812 million gallons, the greatest depth of water being 75 feet; however the depth by which it could be drawn down, viz. 25 ft. gave an effective storage capacity of 7,110 million gallons. The reservoir was formed by the construction of an earthen dam 7,260 ft. long and 85 ft. high in the deepest part, the width at the top being 30 ft. The slopes were three to one inside and two and a half to one on the outside with 15 ft. berms at R.L's, 175 and 147. The R.L. at the top of the dam was 203 ft., top water level was at 195 ft., and the lowest level to which water could be drawn off, 170 ft. The maximum width of the base of the dam at ground level was 525 ft. The water slope was pitched with diorite blocks 18 in. deep. The interior of the dam consisted of a puddle-wall carried down from a distance of about 6 ft. below the top of the bank to the solid shale. This was 8 ft. wide at the top, battering one in eight outwards to ground level, and inwards below the ground level to the shale foundations. It was protected on each side with selected materials, consisting of red and white clay rammed in layers 6 in. deep sloping one in twelve downwards towards the puddle-wall. The remainder of the dam consisted of similar materials sloping in a similar manner towards the puddle-wall, but rammed in layers 12 in. deep.

In the consolidation of the main wall as distinct from the puddle-wall, methods unusual by present-day standards were adopted. One consisted of using flocks of sheep to tramp down the fill; another was the use of the roller mentioned above. This roller differs from the ordinary type, being built in



Typical Cross-Section of the Wall.

sections with the circumference not round but irregular to afford maximum consolidation. Before it was brought from Victoria to Prospect, it is believed to have been used at Ballarat. It is made of volcanic stone common between there and Melbourne. In use at Prospect it was pulled by a team of at least ten horses, driven by Mr. George Pincott and his brother Tom. The former of these was born and lived his life at Prospect; his son, Mr. Sid Pincott, has been employed in the Board's service since 19th February, 1914.

The roller has not been used since the completion of the bank of the reservoir, and it is now preserved at Prospect.

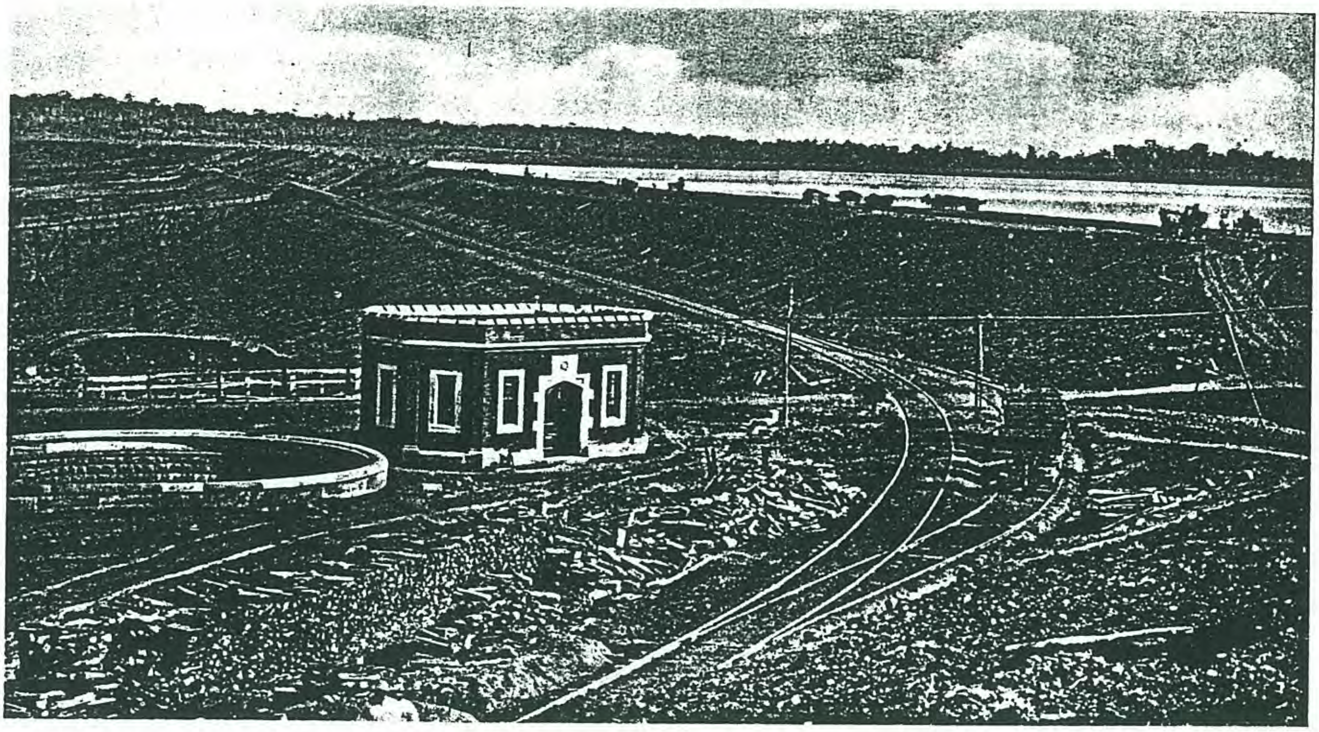
Shortly after the reservoir was transferred to the Board in 1893, movement was noticed on the top of the embankment. Investigation showed that owing to the retentive nature of some of the clay used in constructing the outer slope of the dam, water soaking in from the surface of the slope was being impounded. As a remedial measure, several tunnels were driven in along the base of the embankment, releasing a large quantity of soakage water. The tunnels were then converted into permanent rubble drains and had the effect of checking the movements in the embankment for the time being.

In 1898 the spillway crest level was raised from 195 ft. to 196.67 ft., increasing the storage capacity to 11,029 million gallons.

In the early part of 1897, and again in 1899, when the water level fell over 10 ft. subsidences of the embankment occurred on the inner slope at 4,400 ft. from the north-eastern end of the bank. To remedy this, the toe of the slope for a length of 600 ft. was weighted by the placement of 12,000 yards of blue metal spawls from the Board's nearby quarry, and the clay puddle core was renewed. A new road was also constructed below the embankment to avoid possible damage by traffic passing along the wall.

In 1902, when severe drought caused the water level in the reservoir to be reduced by about 16 ft., further movements in the embankment took place, once more principally at 4,400 ft. and 6,600 ft. from the north-eastern end. This necessitated extensive re-making of the puddle wall down to a maximum depth of 40 ft. and weighting the toe of the embankment. The then Chief Engineer (Mr. J. M. Smail, M. Inst. C.E.), in a report of 1902 stated: "The dam has been examined by the Royal Commission and the Works Department's engineers, and the view of the Board's staff is concurred in, that the movements are entirely local, admitting of treatment, and do not involve the stability of the dam as a whole."

Old Stone Roller.



Prospect Dam Under Construction in 1888.

(Reproduced by courtesy of the Public Library of N.S.W.)

Liberal watering of the embankment was found in later years to check effectively any tendency to movement.

With the transfer of the water storage to the Upper Nepean dams, the inflow through the Upper Canal and the outflow through the Lower Canal can be so regulated that the water level of the reservoir does not fall more than six feet, thus preserving the stability of the embankment. The storage available between the limits of this rise and fall is 1,951 million gallons, which is now regarded as the normal holding capacity of the reservoir from a storage point of view.

The works for drawing water from the reservoir consist of a curved tunnel 932 ft. long, driven through the solid ground altogether clear of the embankment. It is circular in form, 12 ft. in diameter and is brick-lined throughout. Two 48 in. diameter cast iron pipes laid in the tunnel extend from the bottom of the reservoir (thus being ready for use as a syphon should it be necessary to empty the reservoir), through the inlet tower and into a basin to feed the Lower Canal which carries the water to the screening chambers at Pipe Head.

The approach to the reservoir from the Great Western Highway about 7 miles west of Parramatta is a picturesque one, along a tree-lined avenue with the waters of the large lake spreading out to the distant wooded uplands. In the early years, the heavy scrub on part of the slopes surrounding the reservoir was thinned out and over 4,000 indigenous trees of various kinds were planted.

The grounds immediately adjacent to the reservoir where it discharges into the Lower Canal are laid out with garden beds, and with the provision of picnic facilities and a children's playground the area has become a popular picnic spot for the general public.

ADDENDUM TO

HEADWORKS.

OLD STONE ROLLER AT PROSPECT RESERVOIR.

On 18/7/57 I forwarded information to the Public R
Officer giving details of an old stone roller, used in the
construction of Prospect Reservoir, and suggested this infor
could be used for an article in the Board's Journal.

Recently when visiting the Technological Museum in
Street, Ultimo, I saw old stone wheels used for various purp
in early Sydney and I thought that this old roller of uncom
make might be of some historical interest to such an institu
If so the Board might feel disposed to donate it to them,

[signature]
Resident Engine
Headworks.
2/10/57.

Ch. Maintenance Engineer.

Any suggestions please?

Public Relations Offr.

[signature]
CHIEF MAINTENANCE ENG
15 OCT 1957

The information forwarded by Mr. Hill is in my p
and it is proposed to use it for the Journal at a
appropriate time.
I think the Technological Museum might be glad to have the
but before anything is done with it, would like
it photographed.

Chief Mtce Engr.
24 OCT 1957

L. [signature]
24/10/57

Would you please arrange photographing with Mr Dodd?

Resident Engr
Head Works

[signature]
CHIEF MAINTENAN
25 OCT

THE VALVE HOUSES

AND THEIR EQUIPMENT

Commemorative Plaque Nomination Form

To:
Commemorative Plaque Sub-Committee
The Institution of Engineers, Australia
11 National Circuit
BARTON ACT 2600

Date: Oct - Nov 1993

From: Engineering Heritage Committee, Sydney Division

(Nominating Division or Branch)

The following work is nominated for an *Historic Engineering Marker [redacted] award:

Name of work: Prospect Valve Houses

Location, including address and map grid reference if a fixed work: Prospect Reservoir, Sydney.

Owner: Water Board, Sydney

In support of the nomination the following information is provided:

For an Historic Engineering Marker (HEM)

(1) Proposed wording on HEM# see a following page

(2) Justification - please make data as complete as possible.# Original 1887 water control valves still performing design function.

~~**For a National Engineering Landmark (NEL)**~~

(1) Date of construction (or other significant dates).

(2) Names of key professional personnel associated with the work.#

(3) Historic engineering significance of the work.#

PTO

~~(4) Comparable or similar works (a) in Australia (b) overseas.#~~

(5) Features or characteristics setting the work above other engineering works.#

(6) Contribution towards the development of engineering and/or the nation.#

For all Nominations

The following documentation is attached in support of the nomination: (List all documents, photographs, etc, and enclose black and photographs). see following pages

The nomination has been discussed with the owner of the work who has indicated

....

Fully supports plaquing, and plans long-term preservation
(Include statement regarding owner's attitude)

A copy of this submission has been sent to the Secretary of the NCEH

Division at ....
(For completion by a nominating body other than a Division)

In the event of this nomination being approved the nominating body will organise an suitable presentation/ unveiling ceremony.

....
(Chairman of Nominating Committee

....
(Secretary of Nominating Committee

* Delete as appropriate
\# Where there is insufficient space, attach additional papers

I E Aust
crest

HISTORIC ENGINEERING MARKER

PROSPECT VALVE HOUSES

THE TWO VALVE HOUSES WERE COMPLETED IN 1887 AND ARE EXCELLENT EXAMPLES OF FUNCTIONAL COLONIAL ARCHITECTURE. THE UPSTREAM ONE HAS THREE SETS OF VALVES IN A VERTICAL SHAFT FOR DRAWING OFF WATER AT DIFFERENT LEVELS. THE DOWNSTREAM UNIT HAS VALVES FOR CONTROLLING DISCHARGE INTO THE LOWER CANAL. ALL VALVES WERE SUPPLIED BY GLENFIELD OF KILMARNOCK, SCOTLAND, AND WERE INSTALLED AROUND 1882. VENTURI METERS WERE ADDED IN 1907. THE ORIGINAL SYSTEM CONTROLLED SYDNEY'S WATER SUPPLY FOR MORE THAN 100 YEARS.

DEDICATED BY
THE INSTITUTION OF ENGINEERS, AUSTRALIA
AND THE WATER BOARD 1994

THE VALVE HOUSES

INTRODUCTION

The Prospect reservoir has two standard engineering items associated with water storage, a spillway to shed excess water due to the input supply and from stormwater runoff, and a control system for regulating discharge to the users of the water. At Prospect the spillway is a simple wide excavation at the western end of the embankment and has no particular engineering significance other than it is a modified component of the original Prospect Complex. The valve houses and their equipment are far more significant.

THE CONTROL SYSTEM

The attached drawing 216/23 shows the layout of the water control system, collectively known as the Outlet Works because it regulates water going out of the reservoir.

Before describing the system, note the Fisheries Dept buildings which are a reminder of the Trout Farm activities noted in the OVERVIEW part of this submission.

The Outlet Works begin with a trench in the bed of the reservoir, changing into two pipes before reaching the Outlet Tower which is a solid brick octagonal shaft surmounted by a Valve House. At the corners of the the octagonal shaft, the bricks incorporate the angular changes so there are no vertical joints at the corners, hence no troublesome sources of leakage. These angled bricks and the arched openings for the pipes are wonderful examples of the contemporary bricklayers skills. With the integral solid brick base, the shaft is still quite dry inside after more than 100 years of service.

The cross-section marked "Valve Arrangement in Outlet Tower" shows three levels of off-takes, the pipes at the base and two between the reservoir floor and top water level. Many factors, such as stormwater inflow, affect water quality at different depths, so the three off-takes allow the best water to be drawn off.

There are four valves in the shaft, one for each pipe and one for each of the elevated off-takes. The former are 1200mm 3-piece gate valves and the latter are 900mm 1-piece gate valves, all supplied by Glenfield of Kilmarnock, Scotland, and installed around 1882. This early date relates to the fact that the pipes acted as the water diversion from the basin during construction of the embankment.

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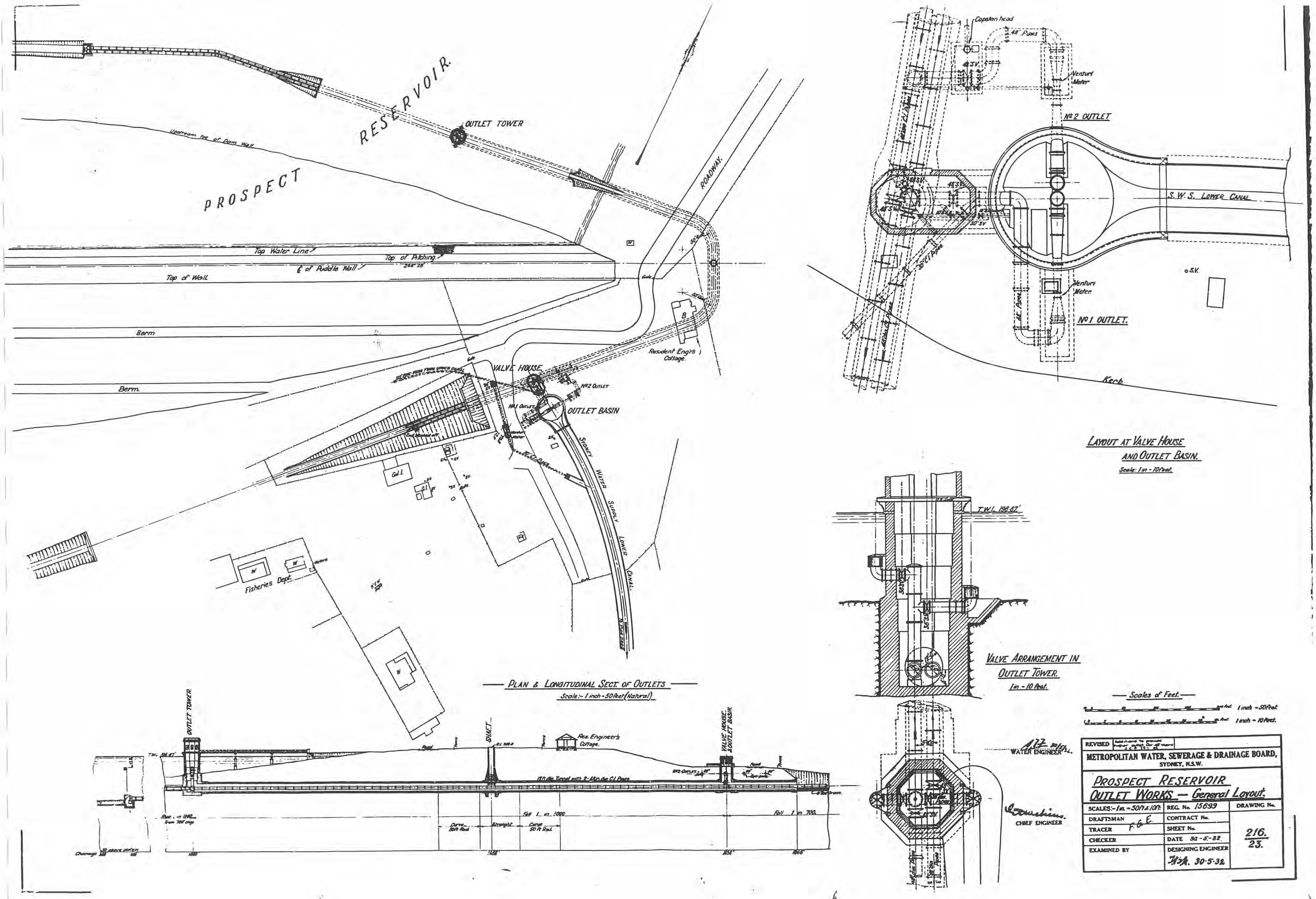
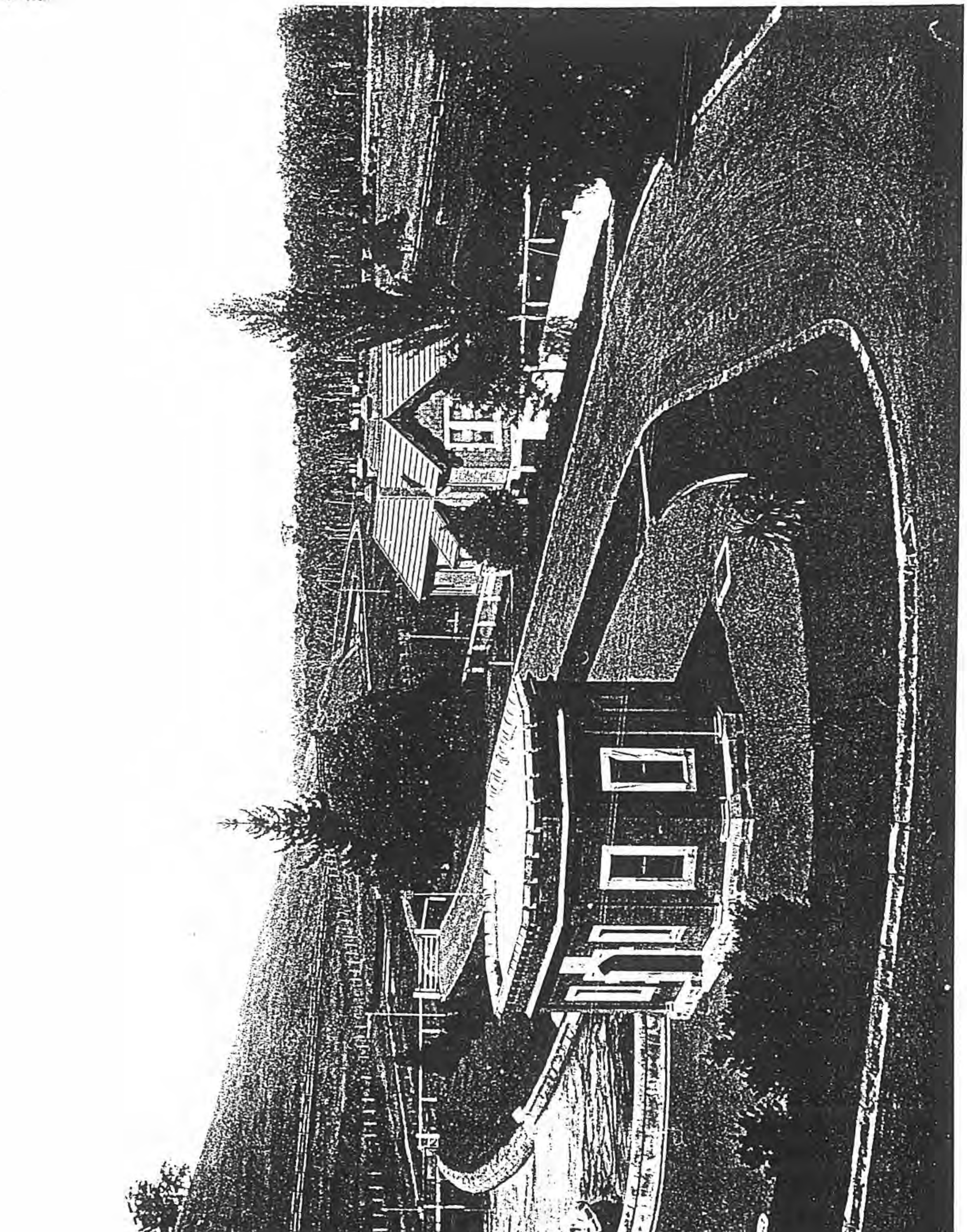
Before describing the system, note the Fisheries Dept buildings which are a reminder of the Trout Farm activities noted in the OVERVIEW part of this submission.

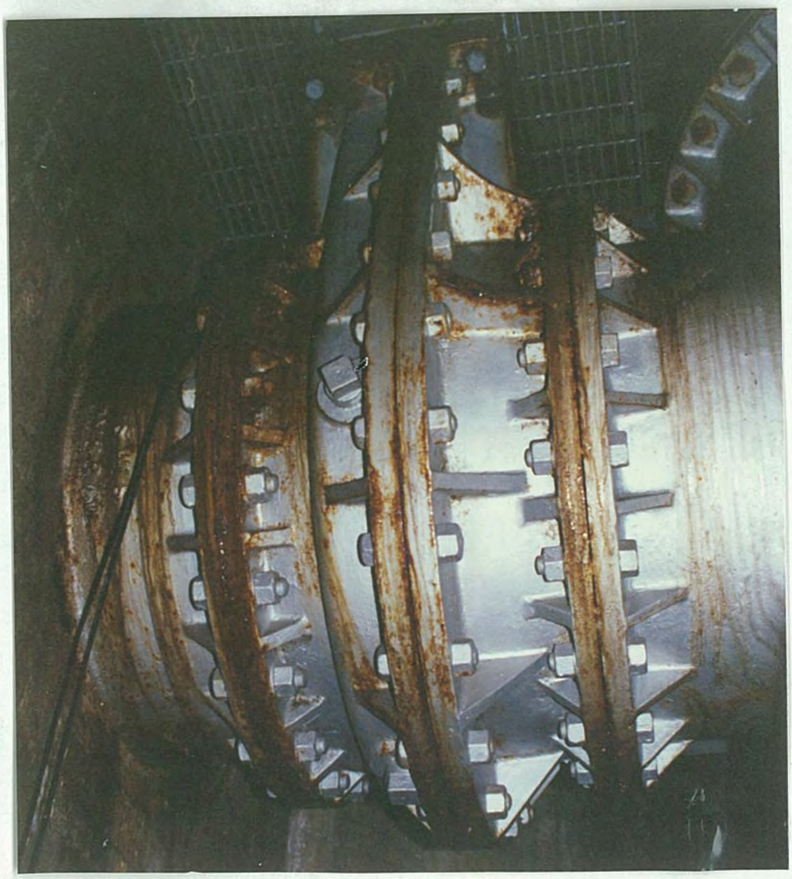
The Outlet Works begin with a trench in the bed of the reservoir, changing into two pipes before reaching the Outlet Tower which is a solid brick octagonal shaft surmounted by a Valve House. At the corners of the the octagonal shaft, the bricks incorporate the angular changes so there are no vertical joints at the corners, hence no troublesome sources of leakage. These angled bricks and the arched openings for the pipes are wonderful examples of the contemporary bricklayers skills. With the integral solid brick base, the shaft is still quite dry inside after more than 100 years of service.

The cross-section marked "Valve Arrangement in Outlet Tower" shows three levels of off-takes, the pipes at the base and two between the reservoir floor and top water level. Many factors, such as stormwater inflow, affect water quality at different depths, so the three off-takes allow the best water to be drawn off.

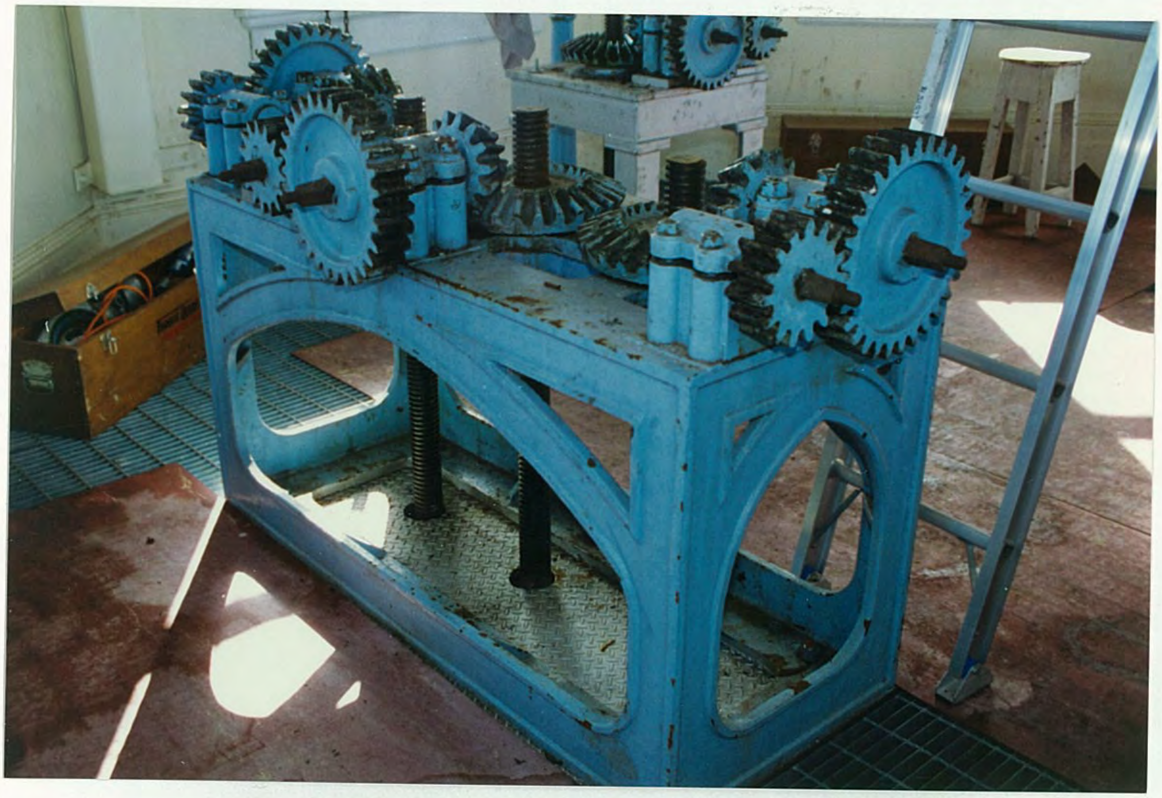
There are four valves in the shaft, one for each pipe and one for each of the elevated off-takes. The former are 1200mm 3-piece gate valves and the latter are 900mm 1-piece gate valves, all supplied by Glenfield of Kilmarnock, Scotland, and installed around 1882. This early date relates to the fact that the pipes acted as the water diversion from the basin during construction of the embankment.

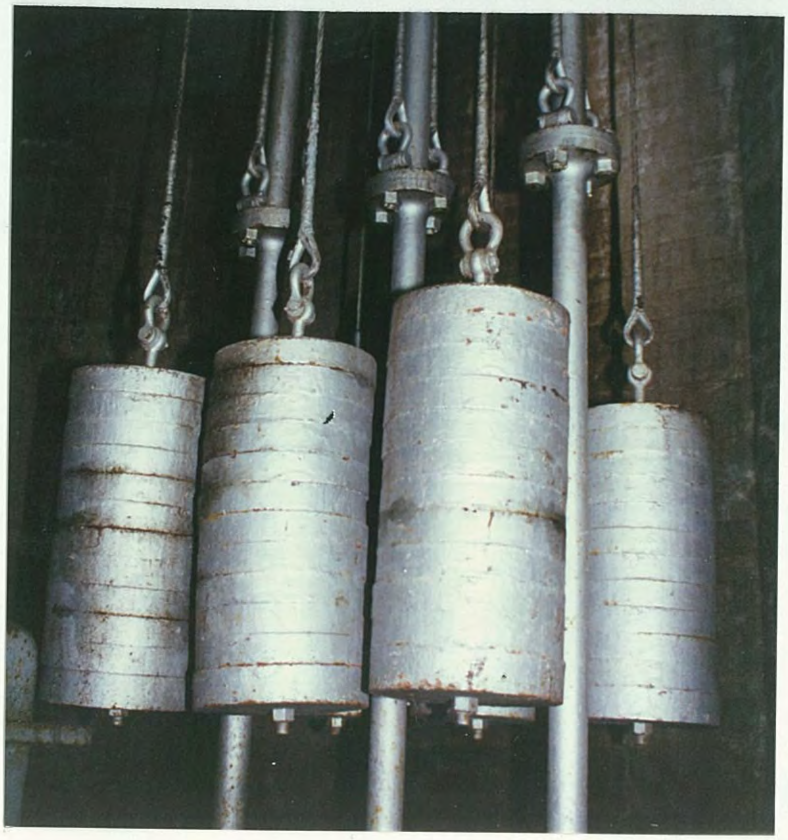

PROSPECT RESERVOIR
OUTLET TOWER
Upstream toe of Dam Wall
ROADWAY.
Top Water Line
Top of Pitching
℄ of Puddle Wall
Top of Wall
Berm
Berm.
VALVE HOUSE
No 2 OUTLET
No 1 OUTLET
OUTLET BASIN
Resident Engrs Cottage.
SYDNEY WATER SUPPLY LOWER CANAL.
Fisheries Dept.
Capstan head
48" Pipes
Venturi Meter
No 2 OUTLET
S.W.S. LOWER CANAL
O.S.V.
Venturi Meter
No 1 OUTLET.
Kerb
LAYOUT AT VALVE HOUSE AND OUTLET BASIN.
Scale: 1in - 10Feet.
T.W.L. 198.67'
VALVE ARRANGEMENT IN OUTLET TOWER.
1in - 10 Feet.
PLAN & LONGITUDINAL SECT. OF OUTLETS
Scale:- 1 inch - 50 Feet (Natural)
OUTLET TOWER
SHAFT
Res. Engineer's Cottage.
VALVE HOUSE & OUTLET BASIN.
Fall 1 in 1000
Fall 1 in 700.
Straight
Curve 50 ft Rad.
Scales of Feet.
1 inch - 50 Feet.
1 inch - 10 Feet.
WATER ENGINEER
CHIEF ENGINEER
REVISED
METROPOLITAN WATER, SEWERAGE & DRAINAGE BOARD,
SYDNEY, N.S.W.
PROSPECT RESERVOIR
OUTLET WORKS — General Layout.
SCALES:- 1in. - 50ft & 10ft.
REG. No. 15699
DRAWING No.
DRAFTSMAN
CONTRACT No.
TRACER F.G.E.
SHEET No.
CHECKER
DATE 30-5-32.
216. 23.
EXAMINED BY
DESIGNING ENGINEER
30-5-32





Each valve is operated from the floor of the Valve House through a simple arrangement of gears that raise and lower vertical shafts. The dead weight of the shafts is balanced by a collection of counterweights so that operation of the valves only involves overcoming some friction and some water resistance. The photographs clarify this brief description.





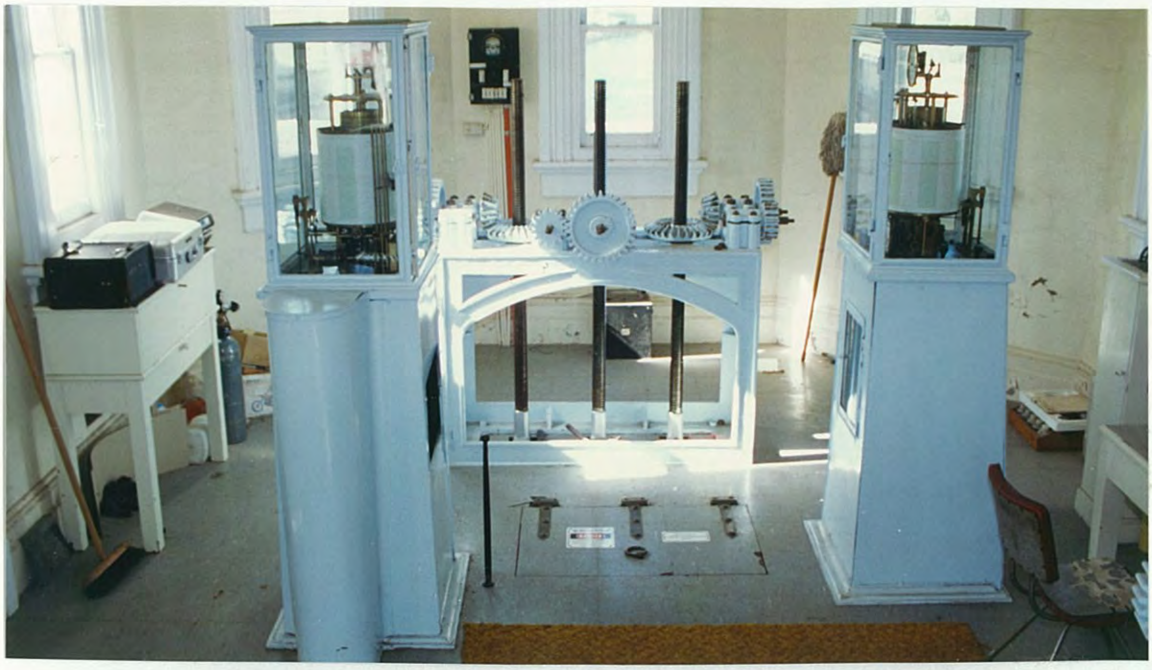
The two outlet pipes leave the Outlet Tower and pass under the east abutment of the embankment and turn 180^{o} to reach the downstream Valve House which has the same magnificent brickwork and stonework as the reservoir Valve House. The pipes continue on for a short distance and emerge from below ground to discharge into an open channel. Each pipe has an original 1200mm 3-piece gate valve in the well below the Valve House.

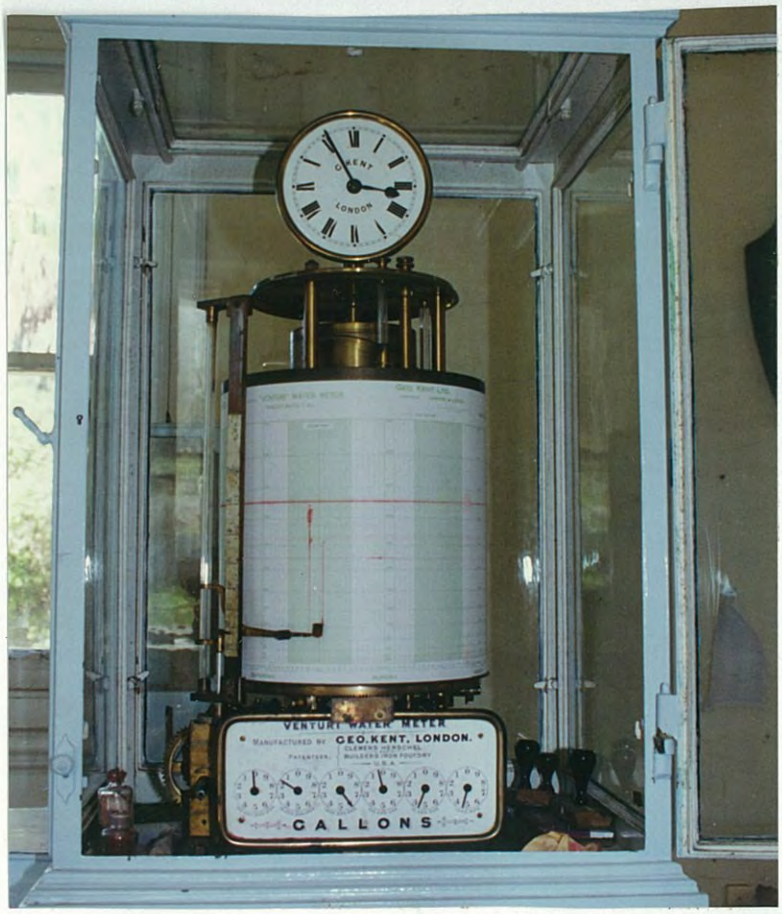
When the reservoir filled in 1888, the diversion function of the pipes and valves ceased, but they are still available in case of an emergency. The function of the downstream Valve House equipment then became that of a regulator of the flow into the Lower Canal.

The downstream Valve House and the upwelling of water discharge into the Lower Canal.

In the early 1900's the Lower Canal was relined with reinforced concrete Monier plates (see next HEM nomination) and the water level was raised thereby increasing the capacity of the canal. In order to supply this extra capacity a new pipe and valve (external to the Valve House) was completed in 1907 and a venturi meter fitted. The existing pipe was modified so as to also include a venturi meter.

The valves under the Valve House are operated by the same system of gears and shafts as in the upstream Valve House, but now there is the addition of the water meter recording unit, see photographs.





The valve gears and recording meter in the downstream Valve House

The commemmorative plaque to E. O. Moriarty is in the downstream Valve House

The National Trust of Australia (NSW Branch) has classified the Valve Houses and their contents, and the Trust has given permission for their documentation to be included with this submission.

PROSPECT (Town or District)	SYDNEY WATER SUPPLY LOWER CANAL GROUP PROSPECT RESERVOIR VALVE HOUSE CARD 2 OF 3 CARD 1 - LOWER CANAL CARD 3 - GREYSTANES AQUEDUCT (Name or Identification of Listing)	Eastern side of Prospect Reservoir UBB Map 60, 4/F CMA 1:25000 Series Prospect, 9030-11-N 064/550 (Address or Location)
Post Code 2164 Local Govt Area		
Author of Proposal J M Collocott		
Date of Proposal September 1986		
Suggested Listing Category CLASSIFIED	Bibliography 1. The Water Supply, Sewerage and Drainage of Sydney - W.V. Aird, Halsted Press, 1961. 2. Sydney Water Board Archives	Owner and Address Metropolitan Water Seweragε & Drainage Board, cnr Pitt and Bathurst Streets, Sydney NSW 2000
Committee (Trust Use) IAC		
Council (Trust Use) APPROVED CL 3/11/86		

Description — Briefly cover the points on the following check list where they are relevant and within your knowledge.

Style / Construction / Use / Architect/s / Builder/s / Date of Construction / Present Condition / History / Owners / Boundaries of proposed listing

1. Introduction and HIstorical Background

1.1 This Classification proposal refers specifically to the sandstock brick val house which controls the discharge of water from Prospect Reservoir to the Lower Canal for conveyance to Pipe Head thence to Sydney.

1.2 Although already covered by the overall Classification for the Lower Canal (made by the Trust inNovember, 1985) it is considered worthy of separate identification and Classification, in its own right, because it contains the official plaque marking the completion in 1888 of the Upper Nepean Water Suppl Scheme and is suitable for permanent preservation as a monument to that hist and vital water supply scheme which was progressively developed over a of 50 years.

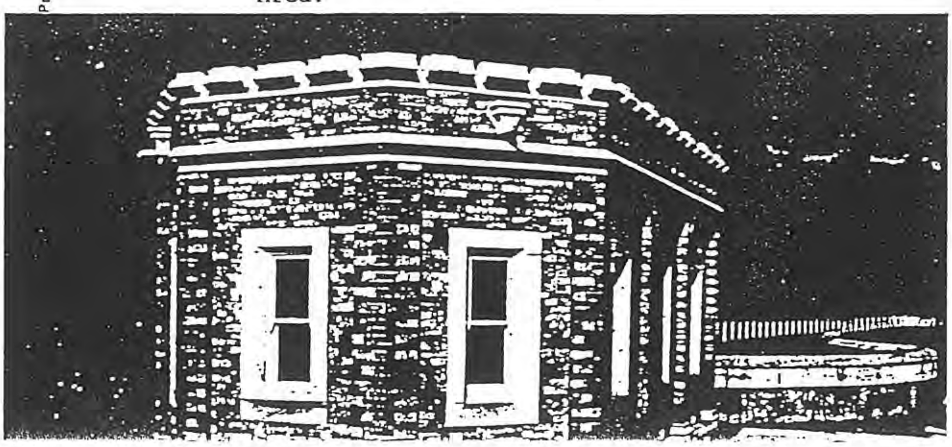
1.3 The Upper Nepean Scheme was the big step from the earlier local water supply sour of Tank Stream, Busby's Bore and Botany Swamps (which in succession soon proved t inadequate) to the ever so much greater and more reliable upland source of the Nep Avon, Cordeaux and Cataract Rivers in the Southern Highlands. The flow of these rivers was diverted by weirs at Pheasants Nest (near Wilton) on the Nepean River, and Broughtons Pass (near Appin) on the Cataract River, into a series of tunnels,

(see ov

Reasons for listing

The Prospect Reservoir Valve House was a key element in the Upper Nepean Water Supply Scheme, which provided a reliable water supply to Sydney upon its construction in 1888. Since that time it has continued to be an essential component of subsequent water supply schemes and still regulates the release of water from Prospect Reservoir to the Lower Canal for conveyance to Pipehead and thence to the Sydney distribution system. It has therefore played an important role in the history and development of Sydney. The valve house building itself is a fine example of civil engineering architecture of the late nineteenth century. Its form and colour today mark it as an attractive element of social interest within the Board's Prospect Reservoir Recreation Area.

Proposal NTN.05



1.3 aqueducts and open channels, collectively known as the Upper Canal, for conveyance to the newly constructed Prospect Reservoir. The ever-increasing demand for more and more water for the rapidly growing city was met by the successive construction of main storage dams on the four rivers over the years from 1907 to 1935.

1.5 The National Trust has already Classified the Cataract, Cordeaux, Avon and Nepean Dams, together with the Upper and Lower Canals and Prospect Reservoir, the cards for which give a comprehensive description of the Upper Nepean Water Supply Scheme.

2. Description

2.1 The valve house consists of an octagonal shaped building some 10 metres long by 6 metres wide. It is constructed basically of sandstock bricks with sandstone foundations and features, and, whilst being entirely functional in its purpose of housing the quite extensive valve gear, it is elegantly proportioned so as to have an aesthetic appeal in its own right. It illustrates the way in which many civil engineering structures of the period had their basic functional appearance enhanced by restrained decoration without ostentation or gaudiness.

2.2 The valve chambers are lined with crafted brickwork, and much of the valve gear is original, although some components have been renewed. Where this has occurred, the original style and appearance has been preserved.

The valve house also contains what may be the original (or if not original, very old) weight operated "Kent" flow metres which are famous for their accuracy and reliability.

2.3 It was, and still is, a key control structure in the Upper Nepean Scheme in that it regulates the release of water from Prospect Reservoir (maximum rate 100 million gallons (450 megalitres) per day) to the Lower Canal for conveyance to Pipe Head thence to the Sydney distribution system. (Since 1960, Prospect has, of course, been supplied by Warragamba Dam instead of the Upper Nepean dams).

2.4 No doubt it was the significance of this role, coupled with the importance of Prospe Reservoir as Sydney's first water storage reservoir (as distinct from service reservoir) which led to the selection of the valve house as the place for erecting the official plaque to mark the completion of the Upper Nepean Water Supply Scheme. The plaque reads:- "The Metropolitan Board of Water Supply and Sewerage,
'Nepean' Water Supply - Completed AD1889 -
E.O. Moriarty, M.Inst.C.E.
Engineer in Chief, P.W.D."

2.5 Although 1889 is recorded on the plaque, 1888 is the year now recognized as that in which the scheme was completed, whilst, in fact, the first water from it for Sydney was obtained in 1886 by means of a temporary system of pipes and aqueducts, built to fill in unfinished gaps, in order to meet a desparate water shortage caused by the near total depletion of the Botany Sqamps.

3. Boundary and Curtilage

The boundary for the Classification would appropriately be the walls of the buildin with a curtilage of the surrounding paved area, but limiting the paved area to two metres from the walls of the building where, in some parts, it is more extensive.

4. Plans and Photographs

Besides the up to date slides and coloured print supporting this proposal, the following also have been supplied for filing in the Trust records:-

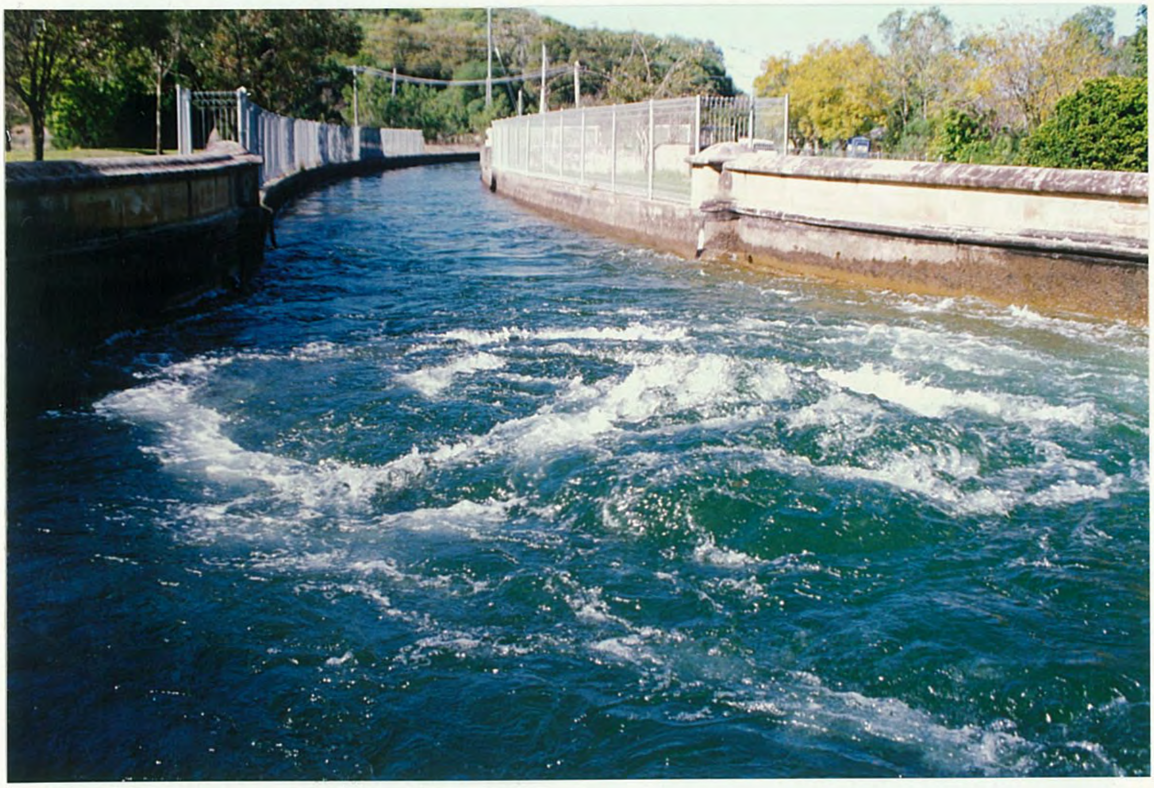
(i) Copies of two original plans, one, a general layout dated 1886, and another, date indecipherable, showing the layout of the valve house and valve operatin gear.

(ii) Copies of four 10 x 8 inch contemporary black and white photographs of the valve house and surrounds, two apparently being of the Lower Canal as origina completed in 1888, and two apparently being of the Lower Canal as strengthene and with sides raised, about 1913.

4. (iii) Three photo-copy prints of old photos, one apparently of the original 1888 construction, and two of the amplification work, apparently taken about the time of completion in 1913.

The earlier photographs show a measuring weir which would have been superseded by the Kent venturi flow meters previously mentioned.

THE LOWER CANAL



Commemorative Plaque Nomination Form

Date: Oct- Nov 1993

To:
Commemorative Plaque Sub-Committee
The Institution of Engineers, Australia
11 National Circuit
BARTON ACT 2600

From: Engineering Heritage Committee, Sydney Division

(Nominating Division or Branch)

The following work is nominated for an *Historic Engineering Marker/[redacted] award:

Name of work: Lower Canal

Location, including address and map grid reference if a fixed work: Prospect Reservoir to Pipe Head at Guildford, Sydney

Owner: Water Board, Sydney

In support of the nomination the following information is provided:

For an Historic Engineering Marker (HEM)

(1) Proposed wording on HEM# see a following page

(2) Justification - please make data as complete as possible.# The first engineered water supply canal for Sydney, completed in 1888 and augmented during 1905 – 13.

~~**For a National Engineering Landmark (NEL)**~~

(1) Date of construction (or other significant dates).

(2) Names of key professional personnel associated with the work.#

(3) Historic engineering significance of the work.#

PTO

~~(4) Comparable or similar works (a) in Australia (b) overseas.#~~

(5) Features or characteristics setting the work above other engineering works.#

(6) Contribution towards the development of engineering and/or the nation.#

For all Nominations

The following documentation is attached in support of the nomination: (List all documents, photographs, etc, and enclose black and photographs). see following papers

The nomination has been discussed with the owner of the work who has indicated

Fully supports plaquing, and plans long-term preservation
(Include statement regarding owner's attitude)

A copy of this submission has been sent to the Secretary of the NCEH

Division at ....
(For completion by a nominating body other than a Division)

In the event of this nomination being approved the nominating body will organise an suitable presentation/ unveiling ceremony.

[signature]
(Chairman of Nominating Committee

P. [signature]
(Secretary of Nominating Committee

* Delete as appropriate
# Where there is insufficient space, attach additional papers

I E Aust
crest

HISTORIC ENGINEERING MARKER

THE LOWER CANAL

THIS WATER SUPPLY CANAL WAS CONSTRUCTED BY PUBLIC WORKS DEPARTMENT LABOUR FROM 1880 TO 1888. IT WAS ORIGINALLY LINED BY STONE FLAGGING WHICH WERE COVERED BY REINFORCED CONCRETE MONIER PLATES DURING 1905-13, THEN AN ENGINEERING INNOVATION. OTHER ENGINEERING FEATURES INCLUDE SIDE - CAST SPILLWAYS, STORMWATER FLUMES AND THE DISUSED BOOTHDOWN AQUEDUCT. THE CANAL CONVEYED SYDNEY'S WATER TO PIPEHEAD AT GUILDFORD FOR OVER 100 YEARS.

DEDICATED BY
THE INSTITUTION OF ENGINEERS, AUSTRALIA
AND THE WATER BOARD 1994

THE LOWER CANAL

INTRODUCTION

The Lower Canal is the third component of the Prospect Complex and conveys water 8km to Pipehead at Guilford where steel pipes continue the water distribution into the reticulation system. An adequate description of the work appears with the classification citation of the National Trust (NSW Branch) which, by kind permission, follows.

GUILDFORD (Town or District)	SYDNEY WATER SUPPLY LOWER CANAL GROUP LOWER CANAL CARD 1 OF 3 CARD 2 - PROSPECT RESERVOIR VALVE HOUSE CARD 3 - GREYSTANES AQUEDUCT (Name or Identification of Listing)	CMA 1:25,000 series Prospect Sheet-9030-11-N 064/550 to 121/528 U.B.D. Map 60, 4/F to Map 61, 9/K (Address or Location)
Post Code 2161 / Local Govt Area Holroyd Mun		
Author of Proposal: J.M. Collocott		
Date of Proposal: September 1985		
Suggested Listing Category: Classified	Bibliography 1. The Water Supply, Sewerage and Drainage of Sydney - W.V. Aird, Holstead Press 1961. 2. Metropolitan Board of Water Supply and Sewerage-Official Handbook 1913. 3. M.W.S. & D.B. Archives.	Owner and Address Metropolitan Water Sewerage and Drainage Board Cnr Pitt and Bathurst Sts, SYDNEY N.S.W.
Committee (Trust Use): I.A.C.		
Council (Trust Use): APPROVED 4/11/85		

Description — Briefly cover the points on the following check list where they are relevant and within your knowledge.

Style / Construction / Use / Architect/s / Builder/s / Date of Construction / Present Condition / History / Owners / Boundaries of proposed listing

Description

1.

1.1 The Lower Canal is the original conduit built to convey water from Prospect Reservoir (Situated 30 kms west of Sydney) to Pipe Head (situated 22 kms west of Sydney) where the supply is screened before passing into major pipelines to feed large sections of the water supply system of the Sydney metropolis.

It is 8 kms (5 miles) long and has a roughly trapezoidal cross section generally in the order of 7 metres wide by 3 metres deep,with a capacity of 450 megalitres (nearly 100 million gallons) per day.

1.2 It was built as a major component of what is known as the Upper Nepean Scheme which was Sydney's fourth water supply source.

The essential feature of that scheme was, and still is, the diversion of the flow of the Nepean River (below its junctions with the Avon and Cordeaux Rivers) by a weir at a point on the Nepean known as Pheasants Nest, near the township of Wilton, through a 7 km long tunnel to the Cataract River at Broughtons Pass, near the township of Appin, where a similar weir on that river diverts the combined flow of the four rivers through a 58 km system of tunnels, aqueducts and open channels, collectively known as the Upper Canal, to Prospect Reservoir.

1.3 The Upper Nepean Scheme including the Lower Canal was constructed between 1880 and 1888. In later years it was further developed by the progressive construction of major storage dams on the Cataract, Cordeaux, Avon and Nepean Rivers.

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1.3 The Upper Nepean Scheme including the Lower Canal was constructed between 1880 and 1888. In later years it was further developed by the progressive construction of major storage dams on the Cataract, Cordeaux, Avon and Nepean Rivers.

2.

2.1 When the Upper Nepean Scheme was in its final stages of construction, the Lower Canal was described by W.H. Warren, first Professor of Engineering at Sydney University, in a paper delivered to the first meeting of the Australasian Association for the Advancement of Science (Sydney, August, September 1888), as follows:-

"The Canal below the Prospect Reservoir is 4 3/4 miles long, and the cross section is partly with vertical sides, and partly V shaped. The basin and part of the canal are lined with diorite ashlar masonry. The high water level of the reservoir end of the canal is 175.50 above sea level, the level of the top of the canal is the same throughout the entire length of this section, viz. 177.5 ft, this arrangement allows an increased head to be obtained for the works nearer Sydney. Owing to the nature of the ground, 900 ft of this section had to be covered in and is virtually a culvert under pressure. The fall in the canal is at the rate of 6 inches per mile. The water is conveyed over a valley at 44 miles by means of a brick aqueduct of 22 arches each 30 ft span. - - - - - - - The capacity of the canal and six foot pipe from Prospect to Potts Hill, a distance of about nine and five-eighths of a mile is 50 millions of gallons per day."

2.2 Regrettably the "brick aqueduct of 22 arches each 30 ft span", which became known as the "Boothtown Aqueduct", suffered severe structural failure in 1892 when the brick sides of the water channel collapsed and had to be reconstructed.

In 1902, increasing demand for water and the need to strengthen weak sections of the canal lead to the initiation of a programme to effect the necessary remedial works and raise the sides of the canal to increase its capacity.

To begin with, a length of 1909 lineal feet was reconstructed in concrete and 646 lineal feet in monier plates, i.e. precast concrete slabs. An enquiry by the Parliamentary Public Works Committee decided that the monier plates provided the better solution, and, in 1905, Parliament gave approval to use that method for the remainder of the work.

The raising and lining of the whole 5 mile length of the canal was completed in 1912, and included the replacement of the Boothtown Aqueduct by a reinforced concrete inverted syphon, 10 ft 6 ins in diameter, which was built in 1907. This was the largest continuous concrete work of its kind constructed in Australia up to that time.

2.3 The canal, as reconstructed, had its capacity increased from 50 to 93 million gallons per day (227 to 423 megalitres per day) whilst subsequent minor improvements and operational techniques have lead to its being capable of delivering 450 megalitres per day into the Pipe Head screening basin.

2.4 Today, the Lower Canal is paralleled by major steel pipelines to convey water from Prospect to Pipe Head, viz. one at 6 feet (1800 mm) in dia, and one at 7 feet (2100 mm) in dia.

A major electric pumping station has been built at Widemere, near Prospect, to boost the flow through the pipe lines in periods of high demand. Just how the capacity of the system has been amplified to meet modern day demands is shown by the following data:-

	Capacity in megalitres per day	
Conduit	Gravity	Boosted
Lower Canal	450	not applicable
1800 mm Pipeline	275	550
2100 mm Pipeline	410	820

Thus it can be seen that the Lower Canal accounts for 40% of the unboosted total capacity between Prospect and Pipe Head and 25% of the total boosted capacity.

3. Whereas the canal once wound its way through open paddocks, residential and industrial development now presses hard on the boundaries of its reserve and makes it a picturesque reminder of life in earlier days. The land is well grassed with numerous trees.

4. The boundary and curtilage of the proposed classification might be as derives from the following summary:-

   The Lower Canal structures and waterway from the Valve House at Prospect Reservoir at its western end to the inlet bay at the Pipe Head screening basin at its eastern end, including:-

   - The open channel sections, and linings thereof, with any support structures.
   - The covered section including the lining and roof thereof and any support structures.
   - All control structures, stop boards, overflows, scour valves, penstocks, trashracks, screens etc.
   - Bridges across the canal built as part of the original scheme.
   - Ancillary surface drainage systems built to prevent pollution of the canal.

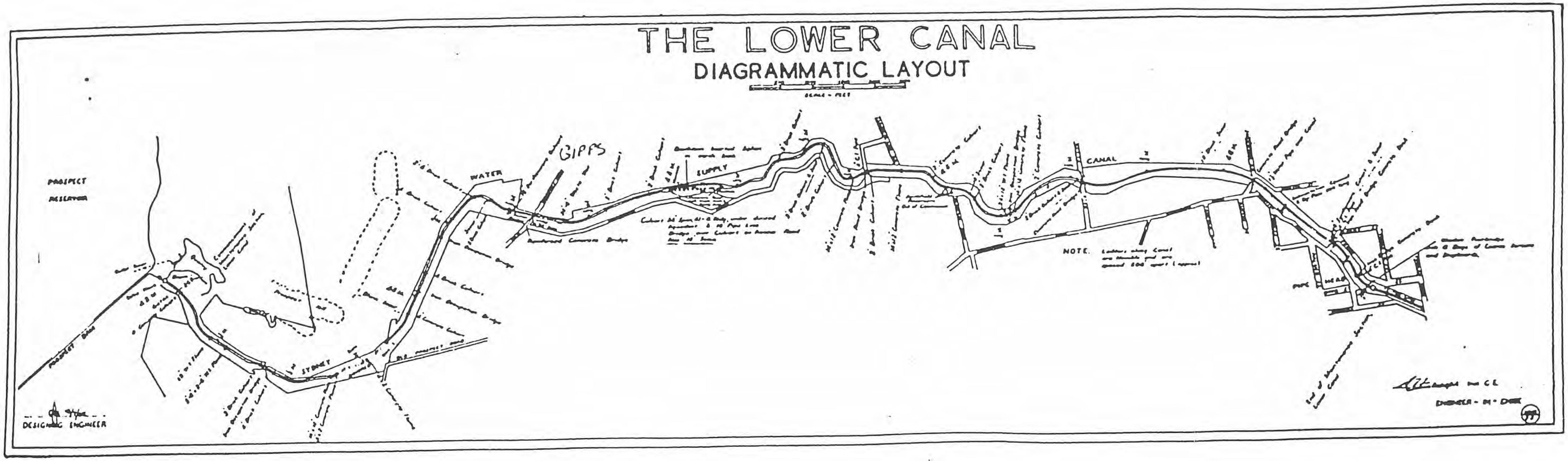
Reasons for Listing

- The historical significance of the Lower Canal as an essential component of Sydney's 4th Water Supply which scheme was the result of the first major engineering investigation into the ever increasing water supply needs of the rapidly growing city.

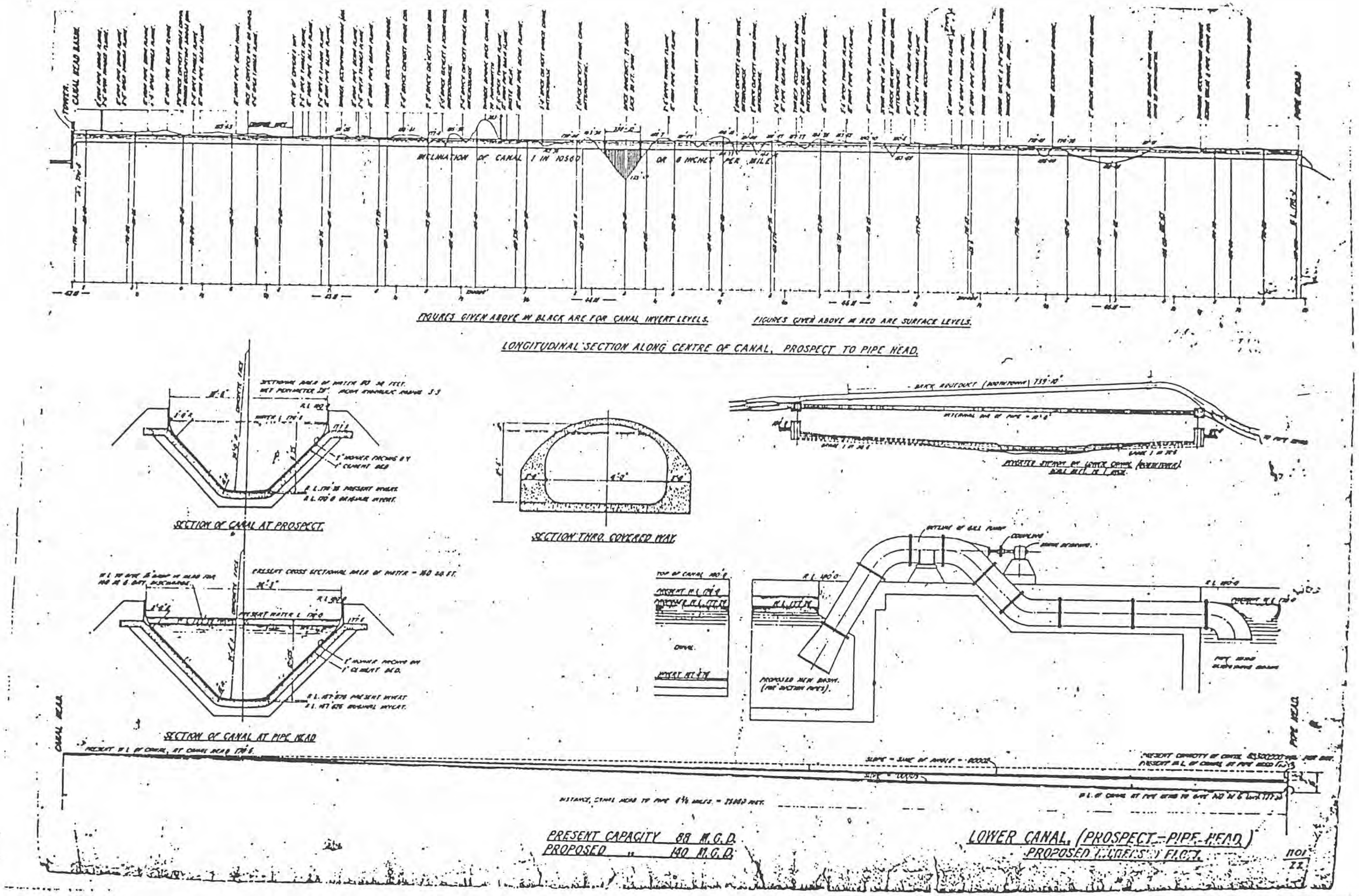
- The engineering significance of the canal as an example of late 19th century hydraulic engineering techniques which, in this case, resulted in the canal having a grade of approximately one in 10,000.

- The ongoing role of the canal as an element of the expanding water supply system.

1-01

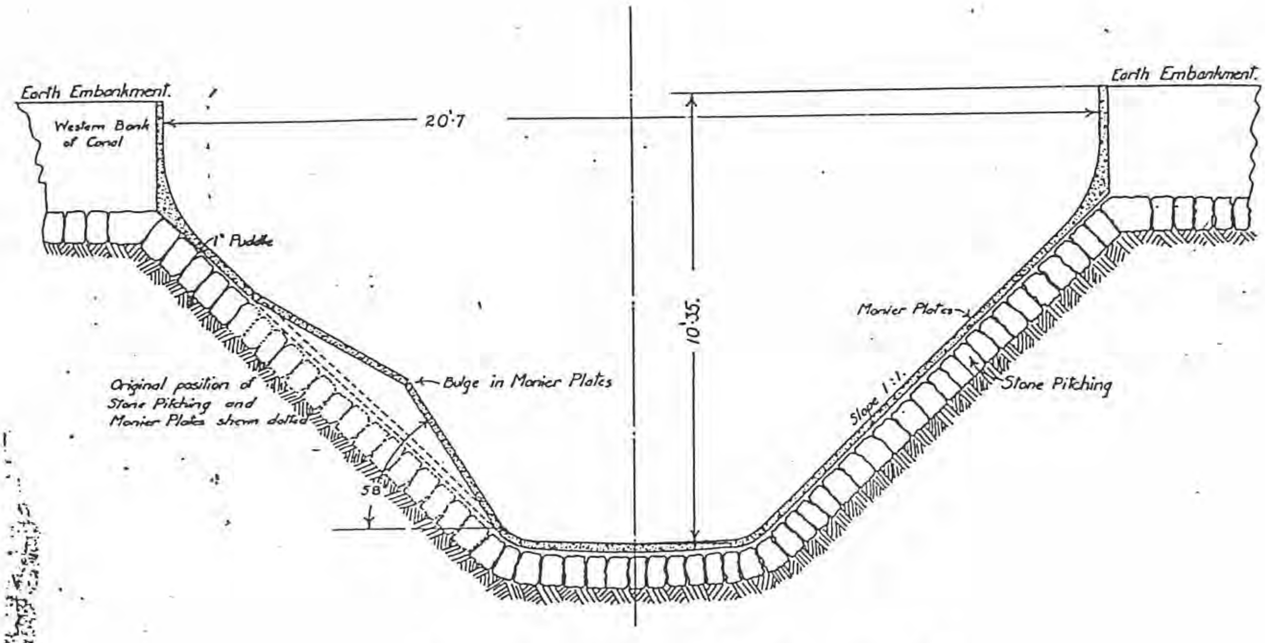

THE LOWER CANAL
DIAGRAMMATIC LAYOUT
PROSPECT RESERVOIR
WATER
SUPPLY
CANAL
GIPPS
SYDNEY
NOTE.
DESIGNING ENGINEER

1e

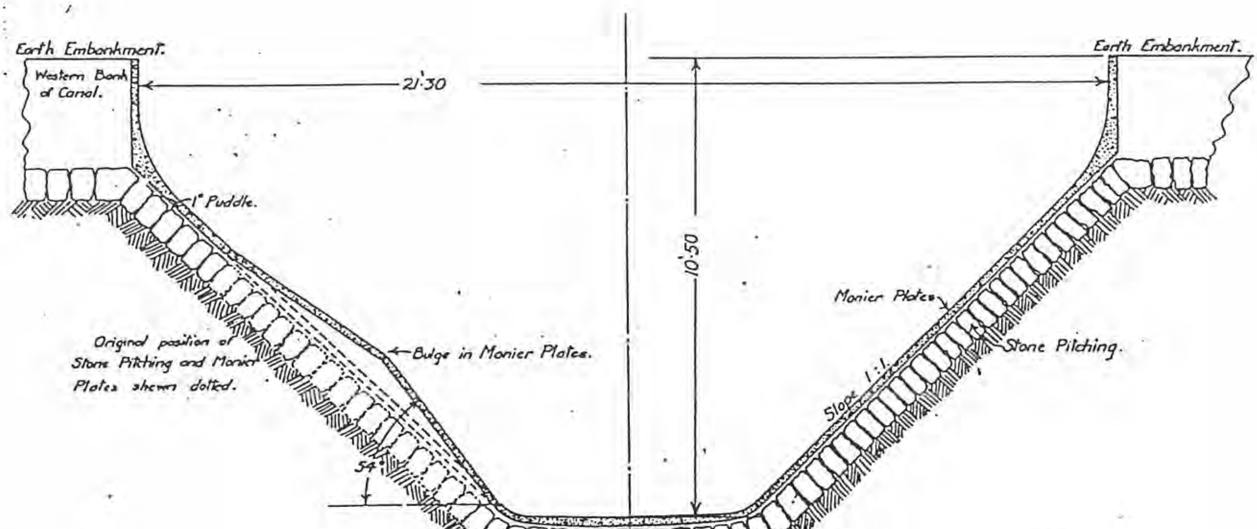

FIGURES GIVEN ABOVE IN BLACK ARE FOR CANAL INVERT LEVELS.
FIGURES GIVEN ABOVE IN RED ARE SURFACE LEVELS.
LONGITUDINAL SECTION ALONG CENTRE OF CANAL, PROSPECT TO PIPE HEAD.
DECLINATION OF CANAL 1 IN 10560 OR 6 INCHES PER MILE
TOWER
CANAL HEAD
PIPE HEAD
SECTION OF CANAL AT PROSPECT.
SECTION THRO. COVERED WAY.
SECTION OF CANAL AT PIPE HEAD
PROPOSED NEW BASIN.
PRESENT CAPACITY 88 M.G.D.
PROPOSED 140 M.G.D.
LOWER CANAL, (PROSPECT–PIPE HEAD)

Bulging of Monier Plates, Lower Canal

Scale ½ to 1ft × 0.71



Cross-Section at 43⅛ miles.



Cross-Section at 43⅝ miles.

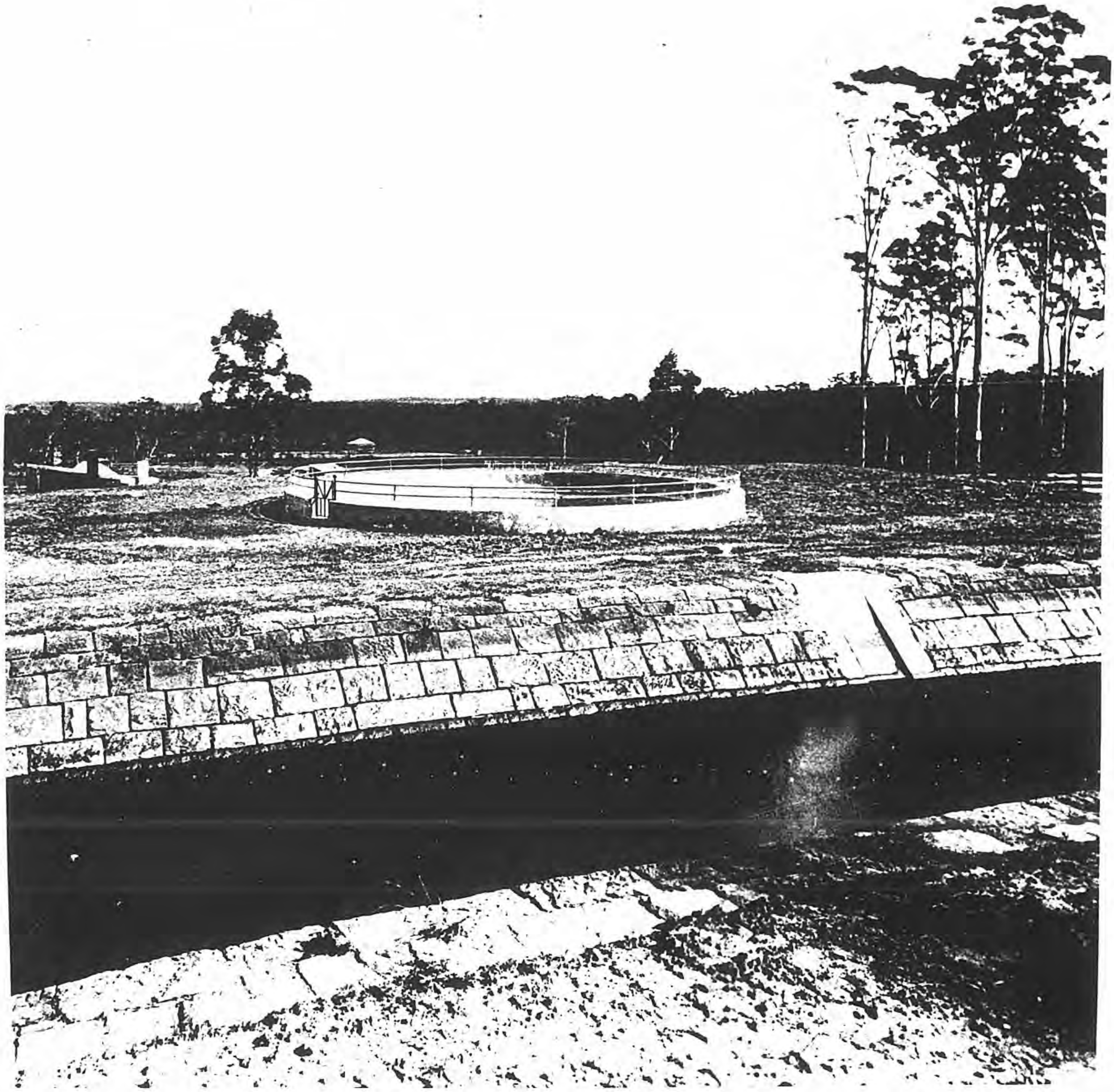
Chief Draftsman.
12.9.21

626
22

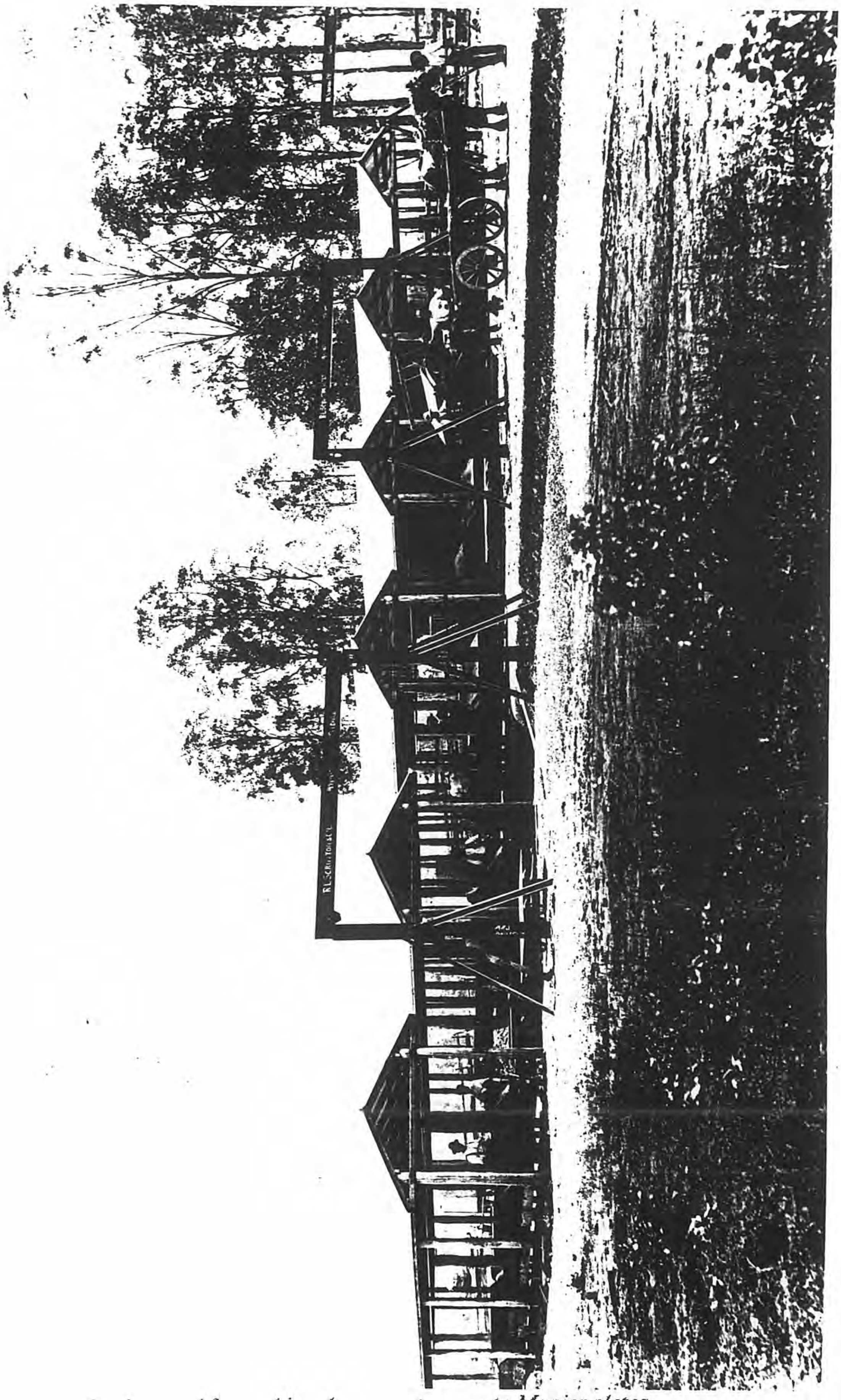
T.L.N.
12.8.21

MONIER PLATE LINING

This was one of the earliest large-scale applications in Australia of the new material, reinforced concrete. Don Fraser's paper "Early Reinforced Concrete in New South Wales, 1895 - 1915" (I E Aust Multidisciplinary Engineering Transactions, Vol GE9, No2, October 1985) summarises the situation, coppy attached at the end of this submission. The following photographs are of work in progress around 1905 and of its continuing service in 1993.

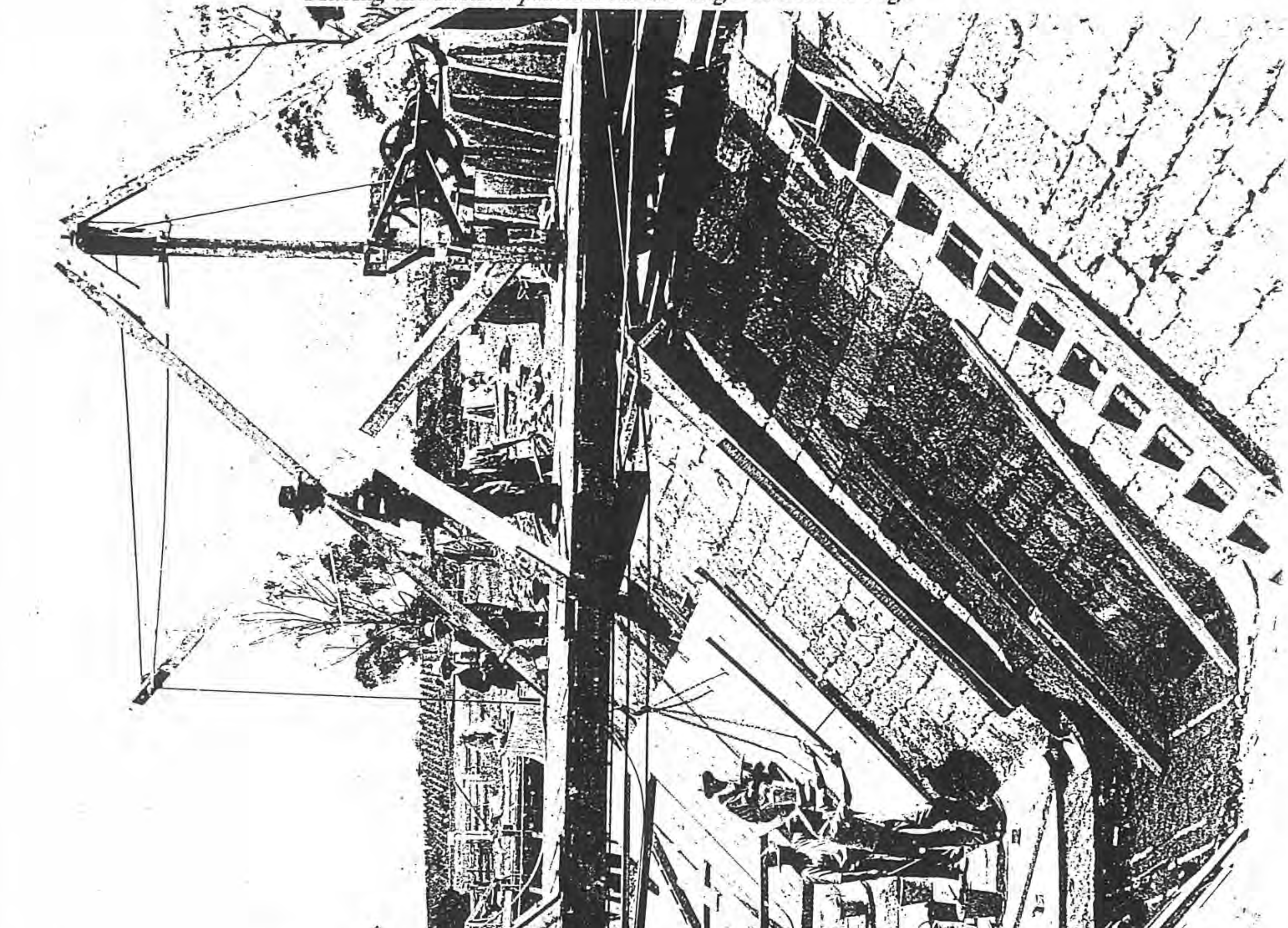


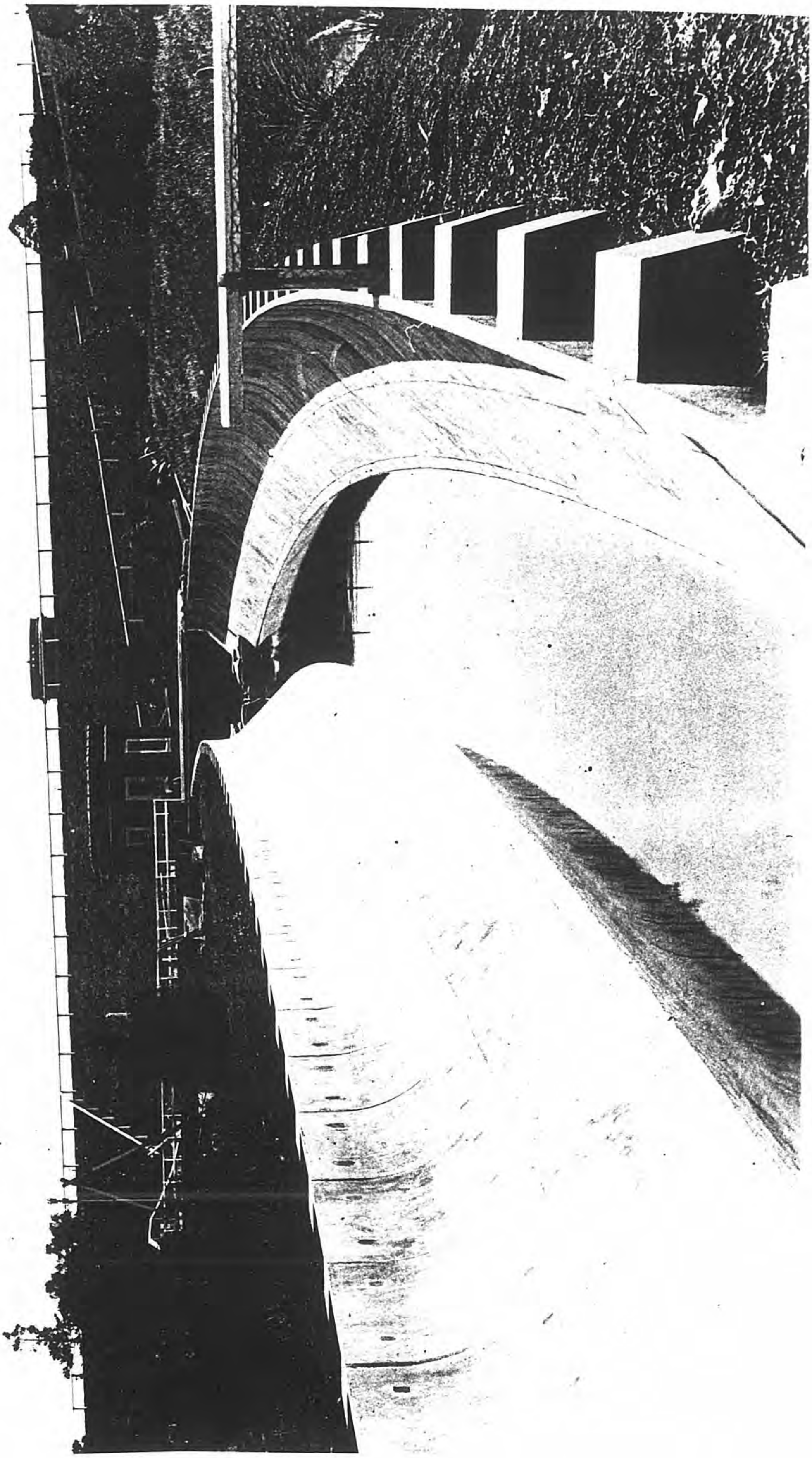
A section of the original Lower Canal and its stone lining.



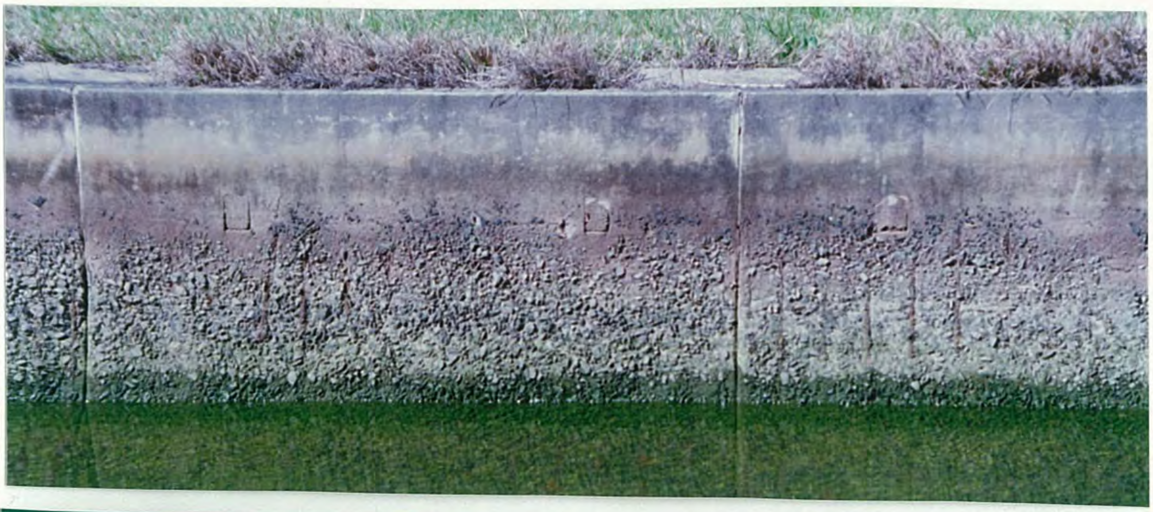
Casting yard for making the precast concrete Monier plates.

Placing the Monier plates over the original stone lining.





The completed Monier plate lining showing how much the Canal was raised.



90-year old Monier plates still in use plus some disused units.

OTHER ENGINEERING FEATURES

Shortly after leaving the Valve House, the Lower Canal skirts around Prospect Hill. At one section the excavation for the optimum alignment caused a steepening of the hill slope which in turn became a maintenance problem. When the Monier plate lining was being planned, the oportunity was taken to rebuild the troublesome sction in the form of a long culvert or covered way.

The designers also applied the knowledge about canals in England to the Lower Canal and incorporated side-cast spillways so that excess water could be discharged at selected locations thereby avoiding overtopping and scouring at other sections of the canal.

Another method of preventing damage was to cut earth drains on the uphill side and lead stormwater runoff to iron flumes across the canal to the downhill side. The following photograph shows one of the original iron flumes still in use.

And finally there is the Boothdown Aqueduct. Again, it is John Collocott's submission for the National Trust classification that adequately describes this structure.

When the Boothdown aqueduct was abandoned the water crossed the gulley by a buried pipe syphon (right).

The
Institution of Engineers,
Australia

Early Reinforced Concrete in New South Wales (1895-1915)

D.J. FRASER, M.I.E.Aust.

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SUMMARY: Reinforced concrete construction began in Europe around 1870, soon after Joseph Monier took out patents for concrete flower pots reinforced by wire netting. The Monier System, as it became known, was extensively used in Germany where it was refined to a viable, economical structural material for a wide range of applications. It was not until the early 1890's that the Monier System was introduced into New South Wales and then with some initial hesitancy and controversy about its use. But after the success of its first major application, the sewer aqueducts in Annandale, Sydney, 1895-97, its development and use grew rapidly. Within the next twenty years, Sydney's structural engineers became as proficient in the theory, design and application of this new technology as their counterparts in Europe, England and America. This paper traces the history of reinforced concrete in New South Wales during those formative years.

1 INTRODUCTION

The use of reinforced concrete in New South Wales began in 1895 when Carter,Gummow & Co. were awarded Contract No.77 by the Public Works Department for the construction of two concrete sewer aqueducts across the valleys of Johnstone's and White's Creeks Annandale, Sydney. At the time, reinforced concrete was known by other names such as ferro-concrete , concrete iron and steel-concrete construction, and by the names of patented methods such as Hennibique, Thacher and Melan Systems. The Annandale aqueducts, figure 1, were built using the Monier System of reinforced concrete arches. These aqueducts are still in service after 87 years.

The first reference to the introduction of the Monier System into New South Wales was not recorded in contemporary technical papers but in the unusual source of the Report, Evidence and Appendices of a Royal Commission (1896-97). The Inquiry was initiated by accusations in the Colonial Parliament that Robert Hickson, Under-Secretary for Public Works, had shown favouritism towards Carter, Gummow & Co and had allowed irregularities in the contractural procedures at a cost to the Crown.

Legally, nothing came out of the Inquiry. Charges were not proved and Hickson and his officers were exonerated. To this extent the Inquiry followed tradition and had been largely "a waste of time and money". But what did come from the Inquiry is a priceless record of the beginnings of reinforced concrete, specifically the Monier System, in New South Wales. Reported fully and contemporaneously, it is information that might not otherwise have been recorded, because subsequent technical papers concentrated on the theory and use of reinforced concrete and only briefly mentioned its origins.

When the two sewer aqueducts were completed in 1897, they were the first large-scale use of reinforced concrete in New South Wales and, in fact, in Australia. Together with John Monash's work in Victoria, the Fyansford and Anderson Bridges, and the 1896 Lamington Bridge in Queensland, these projects established reinforced concrete as the new building material. The emergence of the new technology coincided with the emergence of a new nation, a federated Australia.

Local engineers were quick to recognise the merits of reinforced concrete because the examples in Europe, Britain and America clearly demonstrated its flexibility of application. During the first twenty years of use in New South Wales, a great variety of works were constructed using the Monier and other systems.

This paper presents an historical review of the origins of reinforced concrete and its use, with specific reference to New South Wales and the period 1895 to 1915. The quality of construction was such that a great many of those early projects are still in use and are accessible for inspection. With many of the surviving works 80 or more years old, and with reinforced concrete currently dominating most forms of construction, these early projects have become part of our engineering heritage.

2 HISTORICAL BACKGROUND

Strengthening (reinforcing) masonry and concrete constructions, so as to resist the internal tensions that cause joints to open and cracks to appear, is a very old concept. The Romans are known to have embedded wood, brass and iron within their structures for that purpose, and the practice of including granite keys, metal rods and cramps in stonework, figure 2, was in common use during Medieval and Renaissance times. One of the largest and best examples of the application of this concept is Sir Christofer Wren's use of iron chains around the base of the dome of St Paul's Cathederal to help the concrete resist the tension caused by the outward thrust (Jones and Lakeman 1913, Building Research Station 1956, Cowan 1977 and 1978).

However, the useful principle of combining the high crushing strength of concrete and the high tensile strength of iron into a composite structural material, had to await the availability of cements, hence concretes, that were alkaline and reasonably waterprof thereby forming a reliable protective cover to the iron or steel. This did not occur until the nineteenth century. In 1824 Joseph Aspdin patented his method for making "portland cement" and this new

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material was used extensively in the construction of Marc Isambard Brunel's Thames Tunnel. But it was not in general use until some years later because it was confused with gypsum or "plaster of Paris" which quickly rusted the embedded iron.

By 1855 there were two specific examples of this composite form of construction that should have alerted others to the usefulness and range of its application. J.L.Lambot built a reinforced concrete rowing boat in 1848 and displayed it at the 1855 International Exhibition in Paris, and W.B. Wilkinson constructed suspended concrete floors reinforced by wire ropes, figure 3, in Newcastle-on-Tyne, which he patented in 1854. But it was the maker of flowerpots, Joseph Monier, who set in train the events that led to the development of reinforced concrete as twentieth century engineers know it.

Monier was a gardener in Paris and was manufacturing gardening tools and appliances such as clay flowerpots. When the substitution of concrete still left the finished product brittle, he added a skeleton of iron wires to the moulds and produced durable tubs that were shatter-proof. In 1867 he patented the invention and displayed examples at the International Exhibition in Paris the same year. During the next five years he took out patents for pipes, arch bridges, beams and reservoirs.

In 1879, Monier sold his inventions to G.A. Wayss whose firm of Wayss & Freitag of Frankfurt-am-Main, Germany, made widespread use of them in Germany and Austria-Hungary. A series of strength and durability tests was carried out for him by K. Koenen, figure 4, and a manual was published in 1886 called "Das System Monier". There was now sound theoretical and experimental support for Monier's empirical designs, and Wayss succeeded in introducing the Monier system into public works. Between 1887 and 1891 the firm built 320 arched bridges, some of them with spans up to 40m (130 feet), figure 4.

This German connection is very important to the introduction of reinforced concrete to Australia because the early exponents, J. Baltzer, F.M. Gummow and John Monash were fluent in German and were ideally placed to exploit the new technology in New South Wales, Victoria and South Australia at the end of the nineteenth century.

Meanwhile, parallel developments had taken place in France where Edmond Coignet and Francois Hennibique made significant contributions to the theory and practice of reinforced concrete. Whereas the Monier system was based on the concrete arch in which tension was generally a minor problem, Coignet and Hennibique concentrated on beams and floor slabs in which high tensile stresses made the use of iron or steel reinforcement essential. Their patents of 1906 and 1897, figure 5, have all the characteristics of modern reinforced concrete construction. Subsequent changes over the next twenty years were mainly refinements to the theory and to the details by academics and engineers in Europe, Britain and America.

A more complete history of reiforced concrete (American Concrete Insitute 1976,1982) is beyond the scope of this paper because this brief review is sufficient background to its main theme.

3 PATENTED SYSTEMS

In the second half of the nineteenth century, technological changes were occurring at a rapid rate. Inventions were literall "pouring out of people's minds, off the drawings boards and out of the workshops". Any idea, no matter how trivial, was worth patenting because the subsequent expoitation might be a commercial "pot of gold". So it was with reinforced concrete.

After Monier took out his patents, the usefulness of the new composite material was immediately recognised, but the problem was how to use the new material without paying royalties or facing legal challenges over infrigements of the patent rights. The solution lay in the fact that the concept of reinforced concrete could not be patented, only the method by which it was achieved could be patented (the same applies to prestressed concrete today). Consequently, during the thirty-year period 1870-1900, a great many systems for reinforcing concrete were patented, Table I.

TABLE I
SOME PATENTED SYSTEMS FOR REINFORCED CONCRETE

Allen	Brannon	Clinton
Coignet	Considere	Corr Bar
Cottacin	Dennett	Dentile
Expanded Metal	Hyatt	Hennibique
Indented Bar	Johnson's Lattice	Kahn
Keedon	Klett	Koenen
Lock-woven Mesh	Melan	Moller
Monier	Paragon	Ransome
Scott	Shaler	Thacher
Triangle Mesh	Visintini	

In each case the patent referred to the types of bars and their arrangements, figure 6, as the names Indented Bar and Triangular Mesh suggest. Companies were formed to market many of these patented systems and a host of Manuals and Catalogues (Mouchel 1909, American Steel & Wire Co. 1909, Indented Bar and Concrete Engineering Co. Ltd. c1916) were made available to all potential users. However, by the end of the period under review it was realised there was no valid patent preventing the use of plain reinforcing rods in any formation, consequently, specialist firms came to rely more on their skill and experience rather than their patents (again a parallel situation with pre-stressed concrete).

As for the early years of reinforced concrete in New South Wales is concerned, the dominant systems appear to have been Monier, Hennibique, Indented Bar and Clinton-Paragon.

4 THE START IN SYDNEY

4.1 The culvert at Burwood

Although the Annandale sewer aqueducts of 1895-97 were the first major use of Monier arches, a small Monier arch had been constructed in 1894 for a stormwater culvert, figure 7, located under Parramatta Road, Burwood between Wentworth Road and Philip Street. A drain of similar proportions is there at present, but the records of the Burwood and Concord Municipal Councils do not indicate whether it is the original culvert.

In 1894, the District Engineer for the Public Works Department was W.A.Smith. He stated in evidence to the Royal Commission that the culvert had been built as an experimental arch by Carter, Gummow & Co., and had cost about half the estimated cost of standard brick construction. The Monier culvert had been "tested by a severe strain" and the system had many advantages over conventional forms of construction. The Commission reported "that a moving load across an arch causes bending in other parts of the arch, sometimes flatteneing the curve of the arch, sometimes increasing the curvature of the arch. The iron adds strength to the arch by the added quality of a

Figure 1 Johnstone's Creek aqueduct, one of the two 1896 sewer aqueducts in Annandale, Sydney.

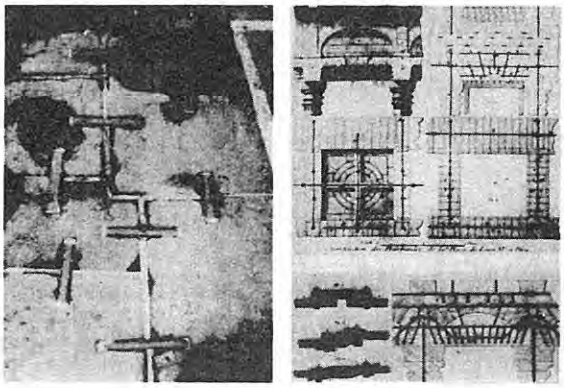


Figure 2 Examples of reinforcing masonry construction during the period 1650-1850.

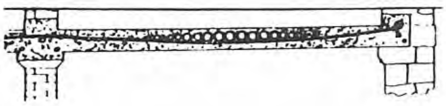


Figure 3 Wilkinson's 1854 patented floor. It incorpoated wire ropes for tensile strength and clay pipes to reduce self weight.

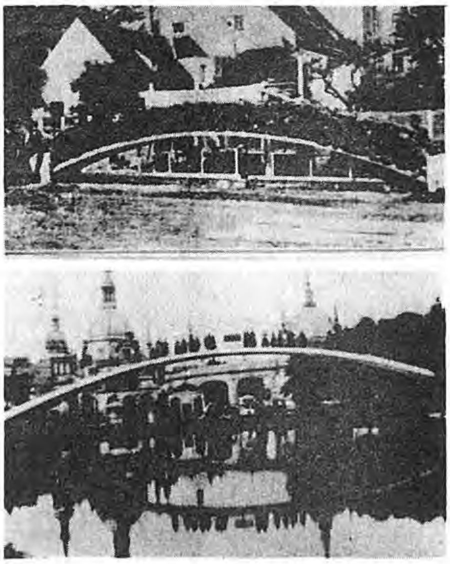


Figure 4
In Germany, a series of load tests was carried out on Monier arches. The success of the tests led to the construction of many large slender arch bridges throughout Europe.

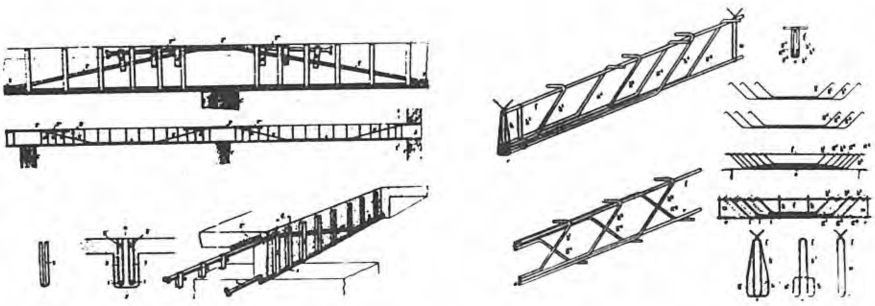
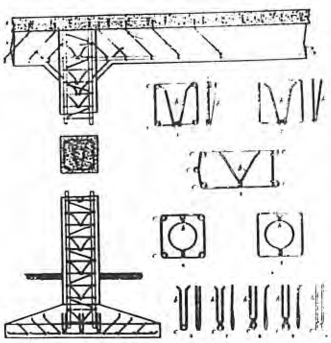
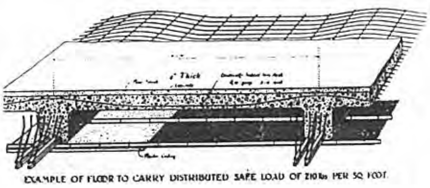


Figure 5 By the early twentieth century, reinforced concrete had acquired many of its modern features as these 1897 and 1906 patents show.





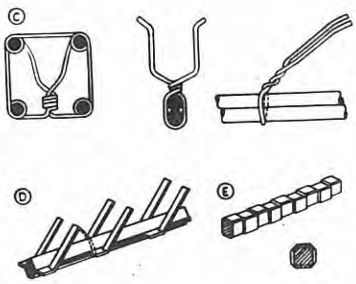


Figure 6 Early reinforced concrete was characterised by a flood of patents such as the Paragon System (top left) and the Clinton Floor (above), and (C) the BRC hoop and stirrup, (D) the Kahn Bar and (E) the Indented Bar.

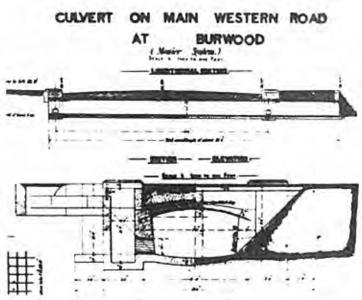


Figure 7
A modest stormwater culvert constructed in 1894 under Parramatta Road, Burwood, using the Monier System began reinforced concrete in New South Wales.

girder. Loads can be imposed at any point".

Robert Hickson, Commissioner for Roads and Bridges, and Engineer-in-Chief for Sewerage Construction, reported on 18 July 1894 "that the culvert was very satisfactory and that he had a firm belief in the system; schemes using the system would be successful, strong and graceful". He was therefore anxious to give it a fair trial and put into pratice this "new departure in engineering". Consequently, when the tenders for the Annandale Aqueducts were reviewed, he approved on the 16th May, 1895 the awarding of the contract to the agents of the Monier System, Messers. Carter, Gummow & Co. plus the payment of a 15% royalty.

4.2 The Inquiry

Hickson's actions led to a furore in Parliament. During construction of the aqueducts, Varney Parkes, MLA alleged "favouritism, defective work, incompetence, violation of terms of contract, and insufficient bond", was critical of the "speciality" nature of the design and expressed a lack of confidence in the ability of those involved to carry it out properly. The Royal Commission was appointed on 21 May, 1896.

The Commission heard evidence from a wide section of concerned parties, politicians, government officers, engineers of the Public Works Department, Contractors, Professor W.H.Warren and consulting engineers such as Norman Selfe. Sittings occurred during the twelve months after its appointment and its final Report was issued late 1897. Hickson and his officers were completely exonerated, indeed some of the original allegations were withdrawn early in the proceedings and the Commission "hinted" that the others were frivolous and precipitated by malice.

To that extent, the Inquiry could be seen as a waste of time and simply a standard ploy of politicians; but in calling all the expert witnesses to give evidence and receiving detailed technical submissions, the Report contains a priceless history of the beginnings of reinforced concrete in New South Wales.

4.3 Introduction of the Monier System

The Report and Evidence of the Royal Commission indicates that W.J Baltzer, a draughtsman/engineer with the Sewerage Construction Branch of the Public Works Department, initiated the use of Monier construction in Sydney, and, it seems, to Australia. He had received his engineering education in Germany and had joined the Department in 1885. He was regarded as a resourceful and capable officer who had designed some major works but, owing to the severe economic depression of the early 1890's, was retrenched in 1895 "with great regret" (Hickson's evidence).

Baltzer had a relative in Germany who was a Professor at the Technical School, Berlin, whom he had visited sometime around 1890. During the visit he toured Germany looking at engineering works and took photographs of many of the Monier arch bridges. When he returned to Sydney he had a letter from the Monier Company (Wayss & Co.) offering to afford him every information.

During 1892-95 Baltzer compiled a set of notes (Mitchell 1922) about Monier construction which subsequently became the 1896 Treatise issued by Carter, Gummow and Co. (see later). It is not clear from the Commission's Report if Baltzer was responsible for the design of the culvert at Burwood, but the inference is strong, however there is no doubt that he designed the viaduct of Monier arches for the Annandale sewer aqueducts.

4.4 The Annandale Aqueducts

Annandale is an inner western suburb of Sydney, located on the southern side of Rozelle Bay and bounded by Parramatta Road further south. Its best known street is the wide, gracious Johnson Street which runs straight from the bay to Parramatta Road along a ridge. To the east is the valley of Johnstone's Creek and to the west is White's Creek; both creeks flow northwards into Rozelle Bay.

During the 1880's Sydney was expanding rapidly due to the boom conditions and the large influx of immigrants. Public works, such as water supply and sewerage schemes, were a major feature of those hectic years. When the large sewer main was planned in 1893 to drain most of the suburbs on the southern side of the Harbour to the Bondi Outfall it was found necessary to carry a branch sewer across Johnstone's and White's Creeks, Contract No. 77.

The original PWD design , figure 8, proposed a series of brick arches for each aqueduct with a total length of about 610m (2000 feet) by 1m (3 ft 6 in) wide and at an estimated cost of £11,298(Warren).

By 1895 the agency for the Monier System was held by Carter, Gummow and Co., a successful firm of contractors, who retained Baltzer as a consultant at a fee of 2½% of any Monier-related contract. He prepared an alternate design for them "out of office hours" based on 25.3m (82 feet 10 inch) Monier arches, figure 8, supporting a reinforced concrete flume at an estimated cost of £9,203. Carter, Gummow and Co. were awarded Contract No 77. Baltzer, of course, was still employed by the Department and so was seen to be in a compromising situation. This was another factor that precipitated the Inquiry.

The Monier arch design was seen by some as being a "speciality" and there were expressions of lack of confidence in the viability of the system and in the experience of all those involved in the project. But these "fears" were dismissed by the support from the overwhelming amount of evidence,for example, Baltzer and his credentials, Monier construction in Germany, the experimental culvert at Burwood, test arches loaded to destruction by Carter, Gummow at Forest Lodge, and the technical evidence by Prof. W.H. Warren and Norman Selfe. Hickson stated that "it was good for the Department to accept the substitute tender and so get valuable experience in this form of construction". Indeed it did, as later works described in this paper show.

Another important factor in the acceptance of the cheaper Monier arch design was the financial climate of the time. New South Wales was still suffering from the deep economic depression 1892-93, therefore, a project that offered substantial technical benefits with a saving in costs of about 20% was welcomed enthusiastically by those responsible for planning and constructing public works during those difficult years.

But did the Colony get value for its money despite the cost advantage of the Monier scheme? The unit cost of the aqueducts was £1.3 per ft^2 in 1896. When indexed to 1984 (Pope 1984) the unit cost is \$1060 per m^2 which compares favourably with current estimates of between \$1200 and \$1400 per m^2. So the Monier System appears to have been cost-effective and the decision to adopt the new technology was justified. However, it was not seen that way in 1896.

The contractors had to agree to £5,000 retention money and maintain and fully guarantee the completed aqueducts for three years. The onus of satisfactory performance of the structure was placed squarely with the contractors.

4.5 Carter, Gummow and Co.

The principals of this company were mainly contractors, Messers. Carter, Forrest, Snodgrass, Maddison and Ewing. F.M.Gummow and W.J.Baltzer (by retainer) were the engineers. The Company had been formed in 1892 and had successes with many projects including the Marrickville sewer scheme covered by Contract No.69. Later on, Cater, Gummow and Forrest became the only principals. In 1896, Baltzer brought to Australia the first machine for making Monier pipes and the Company produced a Treatise (Carter 1896) containing a complete review of the Monier System including photographs and drawings showing the scope of application of this form of reinforced concrete. Making Monier pipes soon became the dominant part of their activities (Gummow 1899) and the new firm of Gummow, Forrest & Co. established the Monier Pipe Factory, figure 9, at Alexandria. Eventually, the Government acquired the works in 1914 (PWD Annual Report, June 30, 1914) and continued business as the State Monier Pipe and Reinforced Concrete Works.

F.M. Gummow, figure 9, was a graduate in Civil Engineering from Melbourne University and by the time of constructing the Annandale aqueducts in 1896 he had some thirteen years of practical experience. Starting at 21 years old he had worked on the Bondi sewer, the Hyde Park sewer, excavations at the Potts Hill reservoir and other similar works in Sydney. In 1892 he was awarded his first contract for water supply works in Adelaide. From 1893 he was a principal with the companies noted earlier and their projects. One of their most successful departures from Monier construction was building the Dunolly Ford Bridge over the Hunter River at Singleton, figure 9, during 1904-05 (Dunolly Ford Br. Souvenir,1905).

5 THE MONIER SYSTEM

The definition of Monier construction seems mundane today,but ninety years ago this new material was viewed this more interest. It had a degree of notoriety because it had figured prominently in the Inquiry, so much so that the popular newspaper "Town and Country Journal" carried a feature article about it in the issue of October 10, 1896. Extracted from Gummow's Treatise of January 1896, the article said,

> "The system of construction consists of iron rods placed longitudinally and laterally to form a mesh or lattice. The sectional area of the rods and the size of the lattice used, vary with the requirements of the structure, and are ascertained from formulae founded on pratical experiment. The lattice is erected on centring and cement mortar is well rammed through and around it. In setting, the mortar shrinks and gets a firm grip of the iron. The lattice work is calculated to take up and distribute any tension the structure is likely to be subjected to, and it gives elasticity to the body".

The article continued in this flowery style as it mentioned the advantages and applications of the system and quoted some successful examples in Germany.

So new was this technology that it did not appear in Professor Warren's text book of 1894, and there seems to have been an air of mysticism and complexity about it among contemporary engineers because Baltzer introduced his 1897 paper on the subject thus,

> "To make the paper more interesting and easy to follow, the author has refrained from entering into any abstruse calculations or intricate theory, but touching on the general principles, the opinions and experiences of leading engineers and scientists, and the results authenticated tests".

The theory of Monier arches was presented by Walter Beer in 1898. It is ironic, therefore, to find Baltzer, in giving evidence to the Inquiry, saying that "the line of pressure for the Annandale arches lies within the middle third hence there is no need for the grillage of iron". Indeed, the calculation books of his colleagues in the Public Works Department, particularly H.H. Dare and J.W. Roberts, show that for most Monier arches tensile stresses did not occur, or at worst were very small.

However, when the system was applied to free-standing water tanks, the lattice of iron rods was essential to resist the hoop tension, in fact the concrete merely acts as an impervious shell.

6 REINFORCED CONCRETE

In neither of the two early applications of the Monier System was composite action utilised structurally, but when beams and slabs (originally called plates) were to be constructed then a proper knowledge of the composite behaviour was necessary. The theoretical work was started in Europe by Coignet, Koenen who produced "Das System Monier" in 1886, Tedesco, Rabut, von Bach, Otto Gaf and Ritter just to mention a few (Cowan 1978).

Locally, Professor Warren conducted tests (1902, 1904) on cement mortars and reinforced concrete units to determine strength and elasticity, and a series of papers were published dealing with the theory of reinforced concrete beams (Cutler 1896, Woore 1902, Gummow 1904, Warren 1905).

Simultaneously, there was a flood of text books and manuals such as those by C.F. Marsh 1904, W.N. Twelvetrees 1905, F.D. Warren 1906, Prof. E. Marsh 1909, J.P. Brooks 1911 and, B.E.Jones and A. Lakeman 1913. By the beginning of World War I the books on reinforced concrete looked much the same as later books of the 1930's and 1950's, and reinforced concrete had achieved its "modern" image both in terms of design and practice.

7 SCOPE OF APPLICATION 1895-1915

With the success of the Annandale aqueducts, the engineers of the Public Works Department became the leading exponents of the design and construction of reinforced concrete work in New South Wales during the next twenty years. The Annual Reports for that period show the scope of application and the widespread use of the new technology. Other government agencies, such as the Water Board, the Sydney Harbour Trust (later to become the Maritime Services Board) and the Railway Department, embarked on large programmes of reinforced concrete construction which they found to be suitable, economical and durable for the long-term needs of the community.

As the success of these new concrete works became evident and with an increasing influx of information from overseas, engineers and architects in private practice began to include reinforced concrete components such as floor slabs, beams and stairs in their buildings.

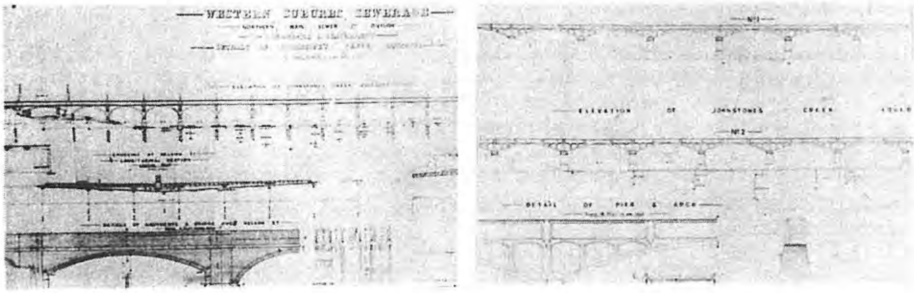
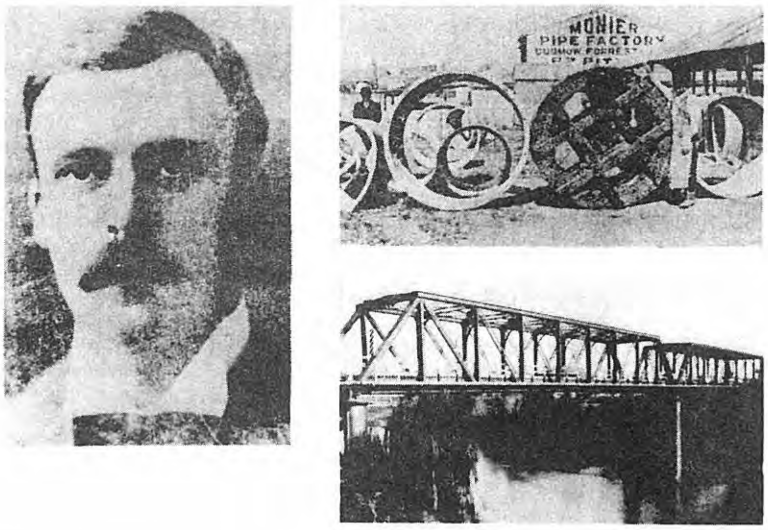


Figure 8 The PWD scheme for the Annandale aqueducts was a series of brick arches (left). The Monier arches (right) were 50% larger in span and their overall cost was 19% cheaper.

Figure 9 F.M. Gummow was the principal pioneer of reinforced concrete in New South Wales. His company built the Annandale aqueducts and fabricated large quantities of concrete pipes. But he was a competent engineer in other fields as the erection of the steel trusses at Singleton in 1904-05 proved.



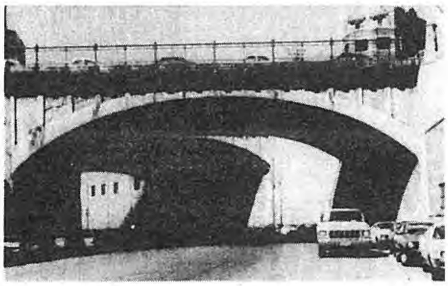


Figure 10 The success of the Annandale aqueducts and of the Monier arch bridges in Germany led to the design and construction of many such road bridges in New South Wales, for example, at Liddell (1898), at Moonbi (1900), at Richmond (1905) , and at Walsh Bay, Sydney.

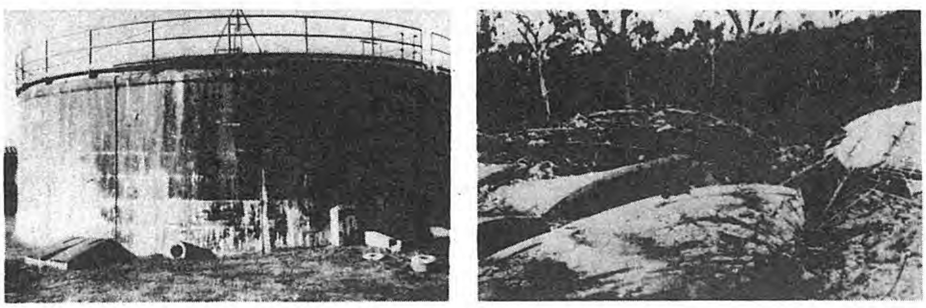


Figure 11 Success and failure in early reinforced concrete construction; the 1899 water tank above Kiama (extant) and the 1909 collapsed Monier tank at Mittagong.

The remainder of the paper is a summary of the scope of application of reinforced concrete between 1895 and 1915. Particularly useful references for identifying those early works are the papers by Bradfield (1900), the discussion to a Warren paper (1907), Mitchell (1922) and the 50th Commemorative issue of Constructional Review (1977). The Archives Section of various government agencies were also valuable sources of information. A very fortunate feature of this study was that nearly all of the examples are extant and accessible for inspection.

7.1 Arch bridges

Monier arches became the dominant form of concrete road bridge from 1896 to 1920, particularly over railways. At the time, the Railway Construction Branch was part of the Public Works Department and the design of Monier arch bridges, for both the road and railway works programmes, was performed by such prominent engineers as Harvey Dare, J.W. Roberts and J.J.C. Bradfield.

A semi-circular concrete arch was built over Black Bobs Creek in 1896 but its proportions are more like a Roman arch than the flatter Monier construction. The first of the new style was built over the railway cutting at Hill Top in 1897 followed by the much larger arch at Liddell in 1898 to carry the Great North Road (New England Highway) over the double track Main North railway, figure 10. A series of railway overbridges followed, over the Main North line between Hornsby and Cowan, the Main South line from Bargo to Cootamundra, and along the Main West from Glenbrook to Lithgow.

In 1900 the Roads and Bridges Branch had their first Monier arch constructed over Moonbi Creek, north of Tamworth, figure 10 (Main Roads 1978) followed by the viaduct of thirteen arches across the Hawkesbury River at Richmond in 1905.

The Sydney Harbour Trust also showed a passing interest in Monier arches and built three over the rock cutting that is Hickson Road passing from Darling Harbour to Walsh Bay, figure 10. These 24 m (80 feet) arches support Munn, Argyle and Windmill Streets, and at the time of their construction 1910 -1914 were noted by the Daily Telegraph (1911) as the "largest reinforced concrete bridges in New South Wales.

7.2 Reservoirs

The Monier System had been successfully used in Germany for water tanks and pressure vessels, consequently the Water Board and the Water Supply Branch of the Public Works Department began building water tanks very soon after the Inquiry had officially endorsed Monier construction.

The first reinforced concrete water tank above ground was built on a hill above Kiama in 1899, figure 11, and soon after, a similar tank was constructed in the south-west corner of the Randwick Racecourse grounds. Beginning with the Mt. Pritchard (Liverpool) reservoir in 1901, the Water Board built a series of on-ground and elevated service reservoirs Howard Street Randwick 1910, Drummoyne 1910 and Bellevue Hill 1912 just to mention a few. The Public Works Department built the water supply tank for Corowa in 1906, and two Monier reservoirs were built for Pelow Main and Neath coal mines in 1908 and 1909 (Henson 1910).

But the introduction of the new technology was not without blemish. On January 22, 1909 the newly-built service reservoir at Mittagong collapsed, figure 11, and spilled 200,000 gallons down the hill (Town and Country Journal, January 27, 1909). E.M. De Burgh inspected the ruins and said "there was no theory as to the bursting, as a number of exactly similar tanks in other parts of the country are all giving entire satisfaction". Errors in construction and some inexperience by the contractors seem to have been the cause, however it did not halt the construction of the elevated service reservoirs that occupy many of the high spots in and around Sydney.

7.3 Monier pipes

G.W. Mitchell (1922), who was Director-General, Department of Public Works in 1914, at the time the government acquired the Monier Pipe Works, claimed that in 1897 the making of Monier pipes was on a small scale because the pipes, made by the European system, had insufficient breaking strength. The design was carefully investigated and numerous tests were made to assess the best amount of reinforcement and its location. The new product "placed Australia ahead of other countries in this section of the use of reinforced concrete". From that time, the use of Monier pipes for sewerage and stormwater drainage became general, and the output of standard units increased rapidly.

Despite the thousands of pipe lengths used , the author has yet to see an example exposed in the ground, but an application of Monier pipes that has been easy to see is their use for bridge piers.

Around 1900, timber piles were still the dominant element of bridge piers, but in spite of the great density and durability of the Australian hardwoods, they were not immune to insect attack and wet rot. Both tended to be most troublesome at the ground line and in the length wetted by the tidal range. Sheathings of copper and Muntz metal had not proved satisfactory but the strength and durability of a reinforced concrete cover offered considerable improvements.

E.M. De Burgh (1900) recognised "that pipes constructed on the Monier principle, in which steel nettings and wires are introduced into the body of the cement forming the pipe, would be very suitable for pile coverings". The first application was in the construction of the road bridge over Cockle Creek, south of Newcastle, in 1901 (DMR archived plan No. 9001714). But Monier pipes, filled with concrete, were also used at many other sites to form the main pier unit, figure 12, instead of timber piles.

7.4 Sea walls

A feature of the introduction of any new technology is that some of its uses are determined by social rather than technical factors. The first use of reinforced concrete by the Sydney Harbour Trust was just such a case. At the turn of the century the shipping and commercial areas of Sydney Harbour were unpleasant waterways due to the presence of dead carcasses, offal and other foul flotsam. The residential strip, between the wharves of Darling Harbour and the City, was a squalid slum and ships' crews did little to control the influx of rats. Consequently, Sydney had a rat plaque, figure 13.

The Sydney Harbour Trust was established to bring some order to and planning for the Harbour and to clean up the mess. One of the problems was the ease with which rats could swim at will and climb up wooden sea walls or run along drainage/sewer pipes into the slum areas. The success of the eradication programme and of the remodelling of the Kent Street-Rocks areas is a very interesting social story in its

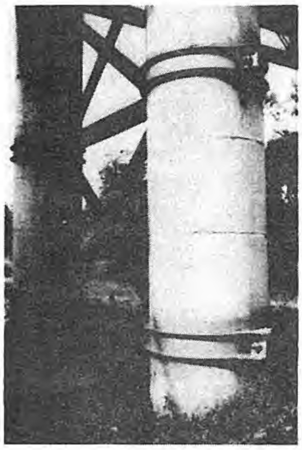


Figure 12 Monier pipes with in-fill concrete were used as piers for road bridges at many locations in New South Wales.

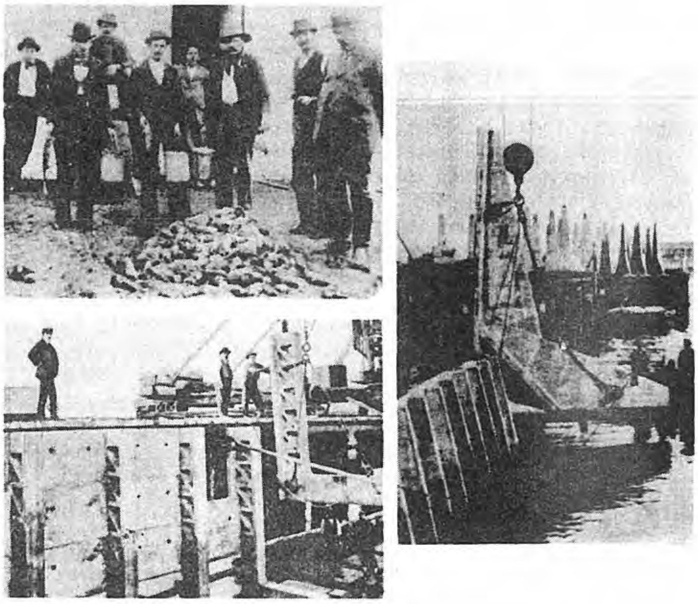


Figure 13 One of the methods for solving Sydney's rat plaque was to build smooth-faced concrete sea walls using precast reinforced concrete units.

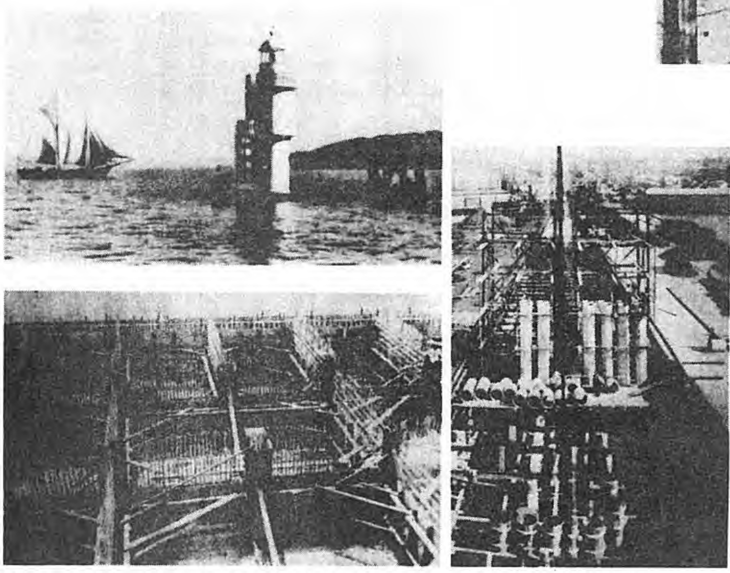
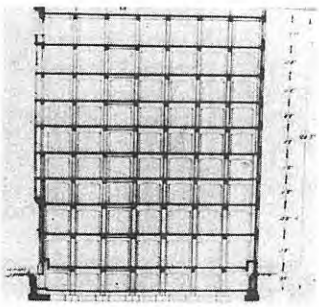


Figure 14 Examples of the scope of application of reinforced concrete for harbour works early this century; a navigation beacon, a pontoon, and the Woolloomooloo wharf.

Figure 15 The canals of Sydney's water supply scheme were liner with reinforced concrete during the period from 1905 to 1913.



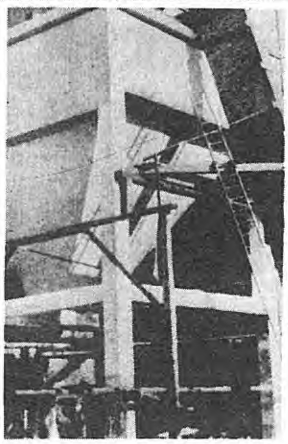


Figure 16 Three examples of reinforced concrete building construction before World War I; the Coogee Beach pavillion and a coal hopper in Parramatta, and the line drawing for No. 49 Wentworth Avenue - the building has reinforced concrete floors.

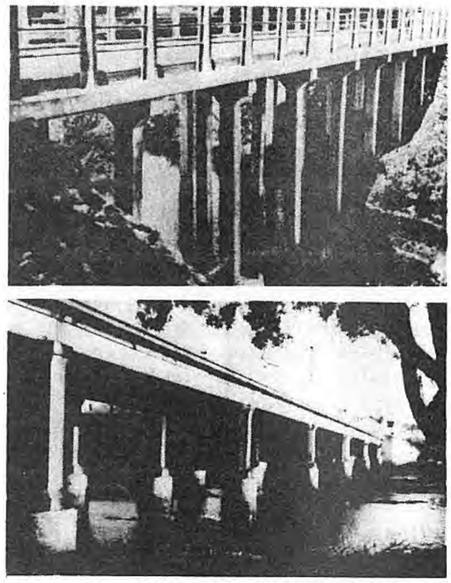


Figure 17 The 1914 slab bridge over American Creek, Fig Tree (replaced); the 1916 beam bridge, Wickham, Newcastle.

own right, but its involvement with the early years of reinforced concrete stems from the use of precast reinforced concrete to form a smooth face on the tidal side thereby effectively restricting the free-roaming habits of the rats.

During the recent reconstruction of the wharves of Darling Harbour north of Pyrmont Bridge, the early precast concrete sea wall was either demolished or abandoned, but south of Pyrmont Bridge and in Walsh Bay, sections remain and are clearly visible at low tides.

7.5 Other harbour works

The Harbour Trust engineers were quick to see other uses for the new material; just three are mentioned here and illustrated in figure 14. Navigation beacons were constructed of reinforced concrete at many locations in the Harbour and on its foreshores.

Wharf decks formed by reinforced concrete slabs were superior to wooden planks, consequently the large programme of wharf construction prior to World War I included such decks as standard practice. When the Trust decided in 1910 to build a new pontoon for Nos. 6 and 7 Circular Quay, timber and iron were rejected in favour of reinforced concrete. The unit was 33m long x 20m wide x 2.4m deep, weighed 600 t and had 44 watertight compartments. The Evening News of November 13, 1913 claimed that it was the largest of its type in Australia.

7.6 Canal linings

The Water Board extended the use of reinforced concrete from service reservoirs to lining the water supply canals, figure 15, during the years 1905 to 1913, and the lined sections are easy to see at the Prospect Reservoir outlet and where roads cross the canals in many places.

7.7 Buildings

From around 1910, architects and structural consulting engineers began to incorpoate reinforced concrete floor slabs, beams, stairs and walls into their building designs. The columns were either cast iron or fabricated steel and the main walls were solid brick; the all-concrete building did not appear until the 1920's. Four existing buildings from the period are the Australian Gas Light building in Parker Street, Ushers/Carlton Hotel in Castlereagh Street, Commonwealth Bank on the corner of Martin Place and Pitt Street, and William Adams' old workshop in Alexandria. Figure 16 shows three early examples of reinforced concrete building construction.

7.8 Slab and beam bridges

By 1914 the theory and practice of reinforced concrete in bending was well understood overseas and and the bridge design engineers of the Public Works Department were ready to extend the application of reinforced concrete from Monier arches to beam and slab construction.

The first of these was a slab bridge,figure 17,over American Creek near Fig Tree, Woolongong, completed in 1914 but recently replaced. In the same year a small slab bridge was built over Tooles Creek south south of Wagga Wagga, which has been widened using beam and slab construction.

There followed in quick succession a series of beam/slab bridges, over Mullet Creek near Dapto in 1916, over Throsby Creek, Newcastle, figure 18, also dating from 1916 (both extant) and over Shark Creek, Maclean. The latter was replaced in 1937 by the present concrete bowstring arch.

With the success of these bridges and the end of World War I, a whole new era of road bridge construction began, so much so that for the next fifty years reinforced concrete was the dominant form of construction.

7.9 Other works

The research into the early use of reinforced concrete is continuing and it is most likely that other applications will be revealed. For example, the author believes that some sections of reinforced concrete road pavement were built in New South Wales around the time of World War I, but has yet to find the evidence.

A reinforced concrete chimney was built at the Ryde Pumping Station in 1916 but demolished in 1982;and some hoppers and silos were built for private companies.

The examples quoted in this paper are far from exhaustive.

8 CONCLUSION

The development and use of any engineering technology is part of the total history of a community. The contemporary social attitudes, politics, economic factors and personalities all influence the success, or otherwise, of that technology. So it was with the introduction of reinforced concrete into New South Wales. Although technical papers from 1898 to 1915 illustrated the developments in theory, design and application, it was the result of a political row and the subsequent Royal Commission that revealed the origins of reinforced concrete in New South Wales.

The experienced historian is well aware of this technical-social interplay and so too must be the engineering historian, because, without identifying the impact of those other factors, the technical story is incomplete.

Reinforced concrete has become, after ninety-five years, a common part of our built environment,and we are fortunate that its durability has allowed a great many of the original applications to be extant. Most of these are actually still in use, and nearly all are readily accessible for inspection. Collectively, they form a significant body of hard evidence of our engineering heritage.

9 ACKNOWLEDGEMENTS

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For photo and biographical details, see page 81

GREYSTANES (Town or District)	SYDNEY WATER SUPPLY LOWER CANAL GROUP GREYSTANES AQUEDUCT CARD 3 OF 3 CARD 1 - LOWER CANAL CARD 2 - PROSPECT RESERVOIR VALVE HOUSE (Name or Identification of Listing)	East from Prospect Reservoir approx. 1.6km running parall[illegible] with Macquarie Road. GRID AMG 1000m REF 9030-091545 (Address or Location)
Post Code 2160 Mun of Local Govt Area Holroyd		
Author of Proposal N. PEEK & ~~MWS & D Board~~		
Date of Proposal AUGUST 1979 ~~amended AUG 1980~~		
Suggested Listing Category CLASSIFIED	Bibliography Water - Key to Development, MWS & D Board Archives of NSW Dept Public Works Papers: Item 83/3140 & Item 85/587ws	Owner and Address Metropolitan Water Sewerage and Drainage Board (NSW Go[illegible] P.O. Box A53, SYDNEY SOUTH. 2000.
Committee (Trust Use) SEE OVER IAC		
Council (Trust Use) APPROVED CL 14/4/80		Advised 22/4/80 & advised amended 23/10/8[illegible]

Description

Briefly cover the points on the following check list where they are relevant and within your knowledge.

Style / Construction / Use / Architect/s / Builder/s / Date of Construction / Present Condition / History / Owners / Boundaries of proposed listing

The brick aqueduct, built in 1883, was originally an integral part of the Board's Lower Canal and was previously known as the Boothtown Aqueduct. The canal was built in the 1880's as a valuable link in the Sydney Water Supply System to carry water from Prospect Reservoir to Pipe Head, from where the water was conveyed by pipeline to Potts Hill and Crown Street Reservoirs.
The Aqueduct carried the canal across a wide gully but not long after completion, the Canal's capacity needed to be increased. This was done by raising the walls of the canal, but since this process was not feasible on the Aqueduct, it was replaced by an underground pipeline in parallel and by-passing the Aqueduct.
In conjunction with this pipeline, at each end, a cement rendered brick building in a castellated style, was built for housing the trashrack and bulkhead used to isolate the pipeline for inspections and maintenance. This work was completed in 1907. The brick buildings are not part of the original Aqueduct construction.
Builders of the approx. 24-arch structure were Kinchela and Metcalfe and the cost was £14,226.0.0.

Reasons for listing

The aqueduct was a very functional and valuable link in the Sydney Water Supply System, helping to carry water from Prospect Reservoir to the reservoirs at Potts Hill.
It is picturesque and, as all pipelines nowadays are built underground, nothing like it may ever be built again.

Sketch p[illegible] Attach [illegible] if any.